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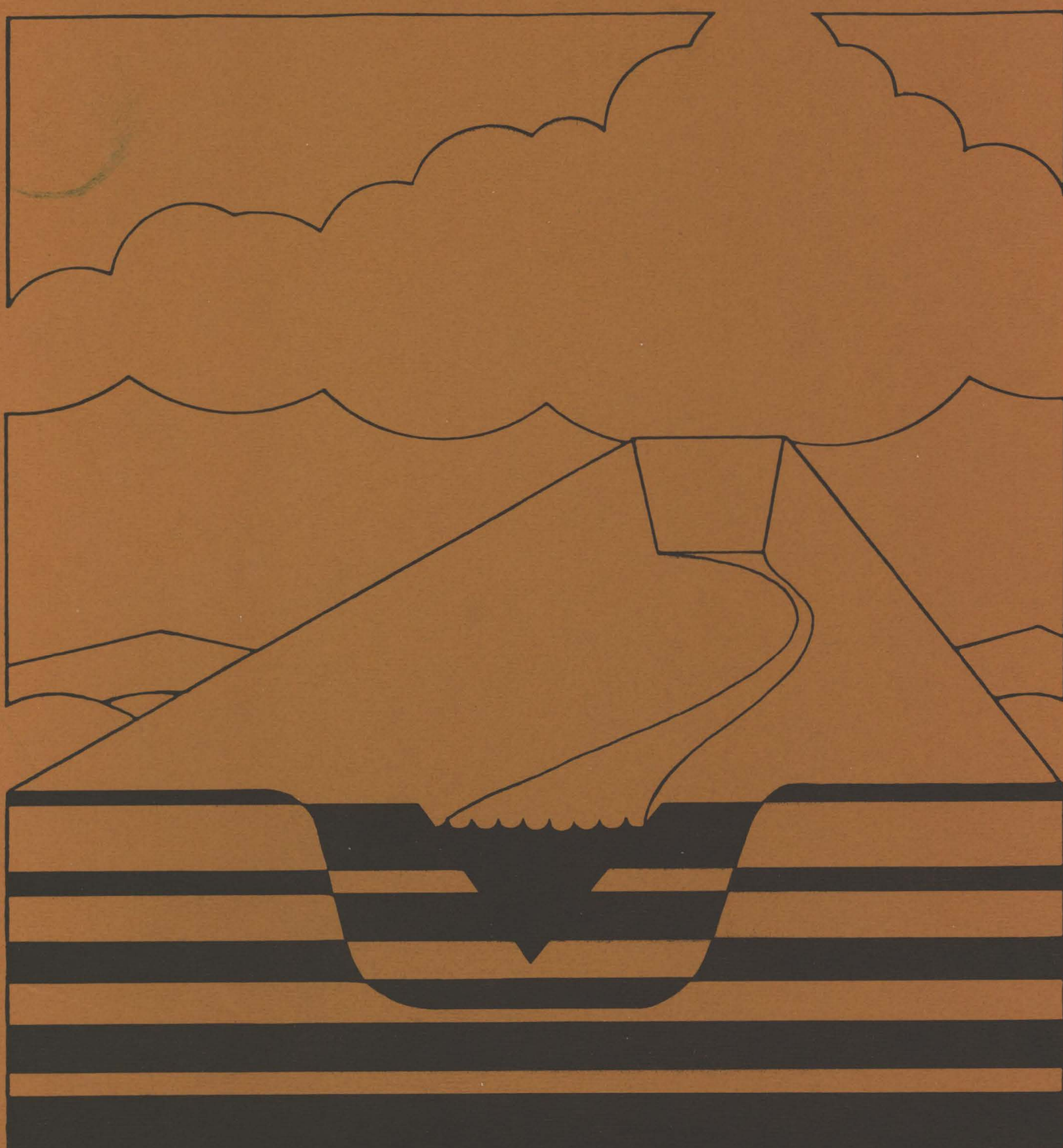
Forest Service

Pacific Northwest Region

Mount St. Helens
Emergency Watershed Rehabilitation Report



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MOUNT ST. HELENS EMERGENCY WATERSHED REHABILITATION REPORT

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ABSTRACT

Mt. St. Helens is located in southwestern Washington within the volcanically active Cascade province. The Toutle, Green, Muddy, and Lewis Rivers are the major drainage basins immediately adjacent to the mountain.

These drainages were active timber harvest areas, except for the roadless area north of the mountain. Drainages northwest and east of the mountain were extensively cut over.

The upper North Fork Toutle River and Green River watersheds were stable and in excellent condition. The Clearwater Creek and Bean Creek tributaries of the Muddy River were in generally good condition except for some debris concentrations and areas of soil mass movements.

The lower Muddy River and its tributary, Smith Creek, had been impacted by past flooding and a high concentration of clearcuts. The Muddy River was a meandering channel. Both streams were generally free of debris, a result of rehabilitation projects.

Most of the area was highly productive fish and wildlife habitat. The streams supported populations of anadromous and resident fish and the lakes supported resident trout fisheries.

On May 18, after a series of minor eruptions, Mt. St. Helen's upper north quadrant collapsed and the ensuing lateral explosion essentially destroyed 148,993 acres of forest environment. The Lewis River drainage was outside the blast zone and is not included in this report. The blast area included 82,056 acres within the National Forest proclaimed boundary. This is generally very steep and broken terrain. Within the 82,056 acres, 21,676 acres are above 4,400 feet in elevation. The area below 4,400 feet with slopes less than 30 percent is 19,955 acres. The balance below 4,400 feet with slopes greater than 30 percent is 40,425 acres.

The blast destroyed vegetation, deposited debris flows, mudflows, and ashfall material and altered topography, which changed the characteristics of the drainage basins. The habitat and fisheries were severely altered. A full range of traditional rehabilitation techniques were considered for each basin but were often found to be useless against the severe conditions.

The North Fork Toutle River watershed exhibits the widest range of volcanic phenomena and consequently has been altered the most. Depths of volcanic deposits exceed 500 feet in some areas. Approximately 7,000 acres of timber no longer exist in place; site productivity has been destroyed; new lakes are forming; Spirit Lake, if filled, could triple in surface area; and the road system has been obliterated.

Sediment yield the first year from this basin, measured at the confluence of Castle Creek, is estimated to be:

overland	3,197 acre-feet/yr.
gully and channel	10,165 acre-feet/yr.

Of this amount, 5,662 acre-feet/yr. will be trapped in Spirit Lake, Coldwater, and Castle Creek by the natural dams.

Peak runoff per unit of area will be the highest in any basin. Spirit and Coldwater Lakes will contain the flows of these subbasins. Vegetation recovery will be very slow on slopes facing the mountain and on debris flows. Sediment yield will be predominantly from gully and channel erosion and will increase as the drainage system develops.

The team's strategy in the North Fork Toutle basin is to take full advantage of natural impoundments for control of peak flows and high sediment transport. It will be most important to monitor these impoundments for performance and safety. Other erosion control measures such as seeding will not be effective control against the severe gully and channel erosion taking place in this basin.

In view of the nature and magnitude of volcanic effects and the downstream protection provided by impoundments, full consideration was given to the proposed land management prescription to not modify the area.

The Green River drainage was impacted less than other basins in the blast area. The headwaters and tributaries nearest the mountain were most affected. The predominant effects were blown down timber and ash depths up to 4 inches. Deeper deposits exist in channels in the headwaters. Some mud flows did occur in side drainages from higher elevations that had snow cover prior to the eruption.

Sediment yield the first year from this basin is estimated to be:

overland	94 acre-feet/yr.
gully and channel	665 acre-feet/yr.

The peak flow will be approximately one half that of more severely damaged basins. This area was mostly roadless and had few clearcuts. Native vegetation is recovering rapidly.

The team's strategy in the Green River basin recognizes previous site values and high potential to recover. Therefore, maintaining soil on the slopes, enhancing revegetation, and minimizing future channel disturbances are key criteria in the course of action.

Down timber is providing an effective barrier to overland sediment yield and should remain in place until the summer of 1981 to allow native vegetation time to establish. In old clearcuts, silt fences can provide the same protection. Seeding is recommended for clearcuts and riparian areas in the upper basin. Channels should be cleared of suspended logs to prevent additional damage and log jams.

The Muddy River drainage has three subdrainages (Smith, Bean, and Clearwater Creeks) within the blast area. Smith Creek and Bean Creek were severely impacted.

The Clearwater Creek drainage is similar to the Green River. The damage is most severe in the upper drainage with heavy ash deposition and blowdown. The ashfall deposit is in three layers: sand, coarse pumice, and fine ash. The lower basin has standing green timber.

Clearcuts were more numerous in the Clearwater Creek drainage than in the Green River drainage. However, the U-shaped valley, lower stream gradient, and remaining downed timber are serving to reduce sediment transport.

Sediment yield the first year from this subdrainage is estimated to be:

overland	358 acre-feet/yr.
gully and channel	1,015 acre-feet/yr.

The peak flow in Clearwater Creek will be approximately one half that of Smith and Bean Creeks. The deeper ash will contribute more to sediment yield here than in Green River.

Vegetation is recovering especially well in riparian zones.

The team's strategy in the Clearwater basin is the same as the Green River. Because of the deep ash, special considerations have been given to the more extensive road system.

The Bean and Smith basins were severely affected by the blast, mudlfows, pyroclastic flows, and super heated ash and pumice up to 15 inches deep. Only in the North Fork Toutle River were blast effects more pronounced.

In addition, the Bean Creek drainage and especially the Smith Creek drainage, were extensively cut over. Both drainages have a high percent of steep slopes and a history of mass soil failures.

Because of the large amount of ash deposition, steep V-shaped canyons, lack of vegetation or downed timber, previous instability, and high peak flows, a high potential to move and deliver large amounts of sediment exists.

Sediment yield the first year from these basins is estimated to be:

<u>Bean</u>

overland	511 acre-feet/yr.
gully and channel	585 acre-feet/yr.

<u>Smith</u>

overland	2,434 acre-feet/yr.
gully and channel	6,000 acre-feet/yr.

The transportation system is not visible in many areas because of the deep ash. Vegetation is recovering slowly.

The team's strategy in Bean and Smith basins recognizes that holding material on the slope is not possible with short-term actions. It will be important not to aggravate an already bad situation. Therefore, the entrapment and accumulation of sediment behind dams, to prevent it from moving off-Forest, has been investigated. Sites for constructing dams were identified and examined. It was concluded that reservoir capacity would not be sufficient, in relation to expected yield, to produce favorable benefits. Minor log jams should be retained to take advantage of the entrapments created.

Long term rehabilitation actions offer the most opportunity.

The Muddy River was not exposed to significant blast effects. Pyroclastic flows and ashfall deposits are limited to the upper basin. The predominant effects are from mudflows and flooding. Vegetation outside the floodplain has not been affected. The upper channels have been scoured badly. There are major log jams in the lower channel. The highest dollar value loss to the transportation system has occurred in this area.

Historically, this channel has transported high concentrations of suspended sediment.

Sediment yield the first year from the total drainage measured at Swift reservoir is estimated to be:

overland	3,300 acre-feet/yr.	1/
gully and channel	9,700 acre-feet/yr.	1/

1/ Includes sediment from Smith, Bean, and Clearwater Creek.

Peak flows are expected to be very high with the threat of major channel changes.

The team's strategy in the lower Muddy River recognizes the meandering nature of the stream. No channel stabilization is suggested in the first year. Log jams will need to be removed to prevent major stream rerouting. One dam was considered which would trap 6,600 acre-feet of sediment at a cost of 4 to 5 million dollars. The value of the loss to the active pool in Swift reservoir was estimated at 1 million dollars.

The drainage basin on the south and southwest side of the mountain had no major blast effects. Depositional effects have created additional gully and channel erosion in Pine Creek and Swift Creek. Historically, these streams have transported ash material from the upper mountain area. The predominant effect was damage to the transportation system. Although the South Fork Toutle River drainage has pyroclastic and mudflows and ashfall deposits, most of the damage occurred off the National Forest. The team did not recommend any short term rehabilitation action in these drainages within the National

Sediment yield from lands within the National Forest boundary estimated to be in excess of 38,000 acre-feet (76 million tons) the first year. Over 85 percent of the total sediment yields will be from channel and gully erosion. There is almost twice as much channel and gully erosion occurring outside the Forest boundary in the North and South Fork Toutle drainages.

Mount St. Helens Emergency Watershed
Rehabilitation Report

I. INTRODUCTION

A. Purpose and Scope - These findings are the result of an investigation conducted by the Emergency Watershed Rehabilitation Team. The team was appointed to provide a short range rehabilitation plan for the Mt. St. Helens area after the May 18 eruption.

The primary focus of the team's investigation was the heavily damaged blast area of the Gifford Pinchot National Forest.

All intermingled private lands within the Forest boundary were included in the investigations since ownership boundaries are not visible in the field and rehabilitation efforts on private and Federal land are essential to protect all owners' improvements.

The team's first concern was short term recommendations. Many traditional watershed rehabilitation techniques were determined not to be useful in these severe conditions. Therefore, some recommendations address long range opportunities.

Items such as reforestation, salvage logging, VIS, and road access were not addressed except where there was a direct relationship to the rehabilitation measures. This report is not intended to assess the damage to all resources.

Continued volcanic activity must be expected and will probably include additional ash, pumice, and gas eruptions with resulting ash and pumice accumulations, primarily north and east of the mountain. It is also probable that the lava dome activity will pass through additional cycles of reconstruction and destruction. Pyroclastic flows and possibly lava flows will be associated with future eruptions. With the onset of winter precipitation and snow accumulation, mudflow activity will significantly increase, particularly in those drainages heading up on the mountain flanks. This report must be reevaluated next spring. Rehabilitation efforts must consider the potential hazard to personnel. Implementing these recommendations will be subject to restrictions made necessary by future eruptions.

The duration of present volcanic activity cannot be predicted. It can, however, be reasonably assumed, based upon past geologic evidence, that the cycle will extend over a several-year period. The most recent previous activity produced eruptive events of varying severity over a period of 27 years.

Significant and unique geologic features have and continue to be created by the Mt. St. Helens volcanic activity. Similarly, there are heretofor unobserved areas of partial or complete plant and animal destruction or modification. Such features as sterile soil surfaces and lakes, natural dams, geomorphology of volcanic deposits, blast features, stratigraphy of deposition, reestablishment of animal and plant life, and the development of a soil profile, provide the opportunity to observe unique natural renewal processes. The scientific value of such an area cannot be quickly evaluated. However, the decision regarding whether it should be left undisturbed must be addressed before irretrievable data is lost or conditions are modified.

The blast area containing significant evidence of volcanic effects is being studied for special management opportunities. The present management prescription provides for curtailment of any site modifying activities until final prescriptions and boundaries are established. Rehabilitation activities will not be allowed in this unit unless it would prevent significant damage to downstream watersheds outside the special management area. In addition, most of the same area is in a Further Study Area resulting from RARE II decisions. Any remedial action must be coordinated with the Forest Plan, which is being revised at the time of this publication.

B. Team Objectives - The objectives of the team were as follows, listed in chronological order:

1. Make a broad overall assessment of the damage and potential damage to the watershed resource and facilities.

2. Analyze available data that can be used in both short term and long-term rehabilitation strategies. Coordinate efforts with other functions, organizations, or agencies.

3. Make recommendations for immediate short-range rehabilitation measures on the Gifford Pinchot National Forest that are needed to protect life, health, and property both on and off National Forest land.

    a. Concentrate on areas where action can have the greatest benefit.

    b. Reduce sediment yield and sediment transport to the Lewis, Toutle, and Green River systems.

        (1) Make estimates of potential flood flows, and the amount of sediment and debris that might be moved downstream from the National Forest boundary, and the timing of this movement.

        (2) Avoid sediment overtopping or escaping from major impoundments created by mud and debris flows, unless it is determined to be beneficial.

(3) Avoid streams changing channels and out of channel flows.

(4) Minimize failure of road prisms and drainage structures.

(5) Determine the effects of timber salvage on sediment yield.

(6) Stabilize land surfaces that show the greatest potential to respond to treatment.

c. Avoid additional loss of preeruption soils and save the natural mulch.

d. Avoid additional impacts on other resources when taking rehabilitation actions.

4. Make recommendations as to how long-term rehabilitation might proceed, and the need for further study or research.

C. Team Membership - Expertise in the functional areas to be investigated are represented by team members. A biography for each member is included in Appendix 1.

II. PREERUPTION WATERSHED CONDITION

The annual precipitation in the area varies from 70 to 140 inches per year. About 70 percent of the annual basin precipitation occurred as streamflow with the highest flows occurring in December, and a second lower peak sometimes occurring in June. The lowest flow occurs in August and September.

Over 50 percent of the annual precipitation occurred as snow with measured maximum snow depth at 4,400 foot elevation averaging 13 feet with depths occasionally exceeding 20 feet. Consequently, snow melt is a major contributor to the streamflow regime.

The North Fork Toutle River began as an outlet flow from Spirit Lake. Watershed conditions in the drainage were excellent. Tributaries to Spirit Lake drained backcountry and uncut timber lands. Mean water temperature was 12.8° C for the period August 1, 1975 to September 30, 1979 with a maximum of 22.0° C and a minimum of 3.0° C. Mean turbidity values were 1.00 NTU's.

Clearwater Creek was a single channel in a steep U-shaped canyon at the headwaters progressing to a steep-walled V-notched canyon drainage in the middle and lower sections. The watershed conditions were generally good with the exception of some debris concentrations and minor mass soil movements. Mean water temperature was 10.0° C for the period August 4, 1975, to September 30, 1979, with a maximum of 16.5° C and a minimum of 3.7° C. Mean turbidity values were 5.0 NTU's.

The main stream of the Muddy River originated on glacial headwaters on Mt. St. Helens and could best have been characterized as a braided, meandering type channel. The stream course shifted, at will, across a broad alluvial plain with the onset of high water or flooding conditions. No defined channel existed. The channels, for both Muddy River and Smith Creek were generally free of debris, a result of previously completed Forest Service rehabilitation projects. Maximum suspended sediment measured was 7490 mg/l on August 21, 1979 as a result of glacial flour. Mean water temperature was 8.9° C for the period August 8, 1975 to September 30, 1979 with a maximum of 18.0° C and a minimum of 0.0° C. Mean turbidity was 21.7 NTU's.

Though all preeruption soil conditions which existed in the devastated area prior to May 18 cannot be covered here in detail, some important general characteristics can be discussed.

Preeruption soil conditions in the Mt. St. Helens area reflected past volcanic activity (Snyder and Meyer, 1971). Most soil formed in deep pumice and ash deposits overlying basic igneous flows and volcanic breccias. Topography and erosionary forces significantly influenced soil development. For example, in the Green River and Clearwater Creek drainages, the shape and low slope gradient of the valley floors had

promoted development of deep soils, while thin shallow soils or deep highly-dissected soils developed on the steep valley sideslopes. Although soils in the Bean Creek and Smith Creek drainages were formed from essentially the same mineral material, the nature of the underlying bedrock caused very steep, deeply-incised drainages to develop. Landslide activity occurred on a large scale in the past.

Soils in the vicinity of Mt. Margaret, Mt. Whittier, and Black Mountain tended to be very shallow with significant areas of rock outcrop. Past glacial activity and associated erosion has effectively removed most soil material.

Soils in the Coldwater Basin were similar to those found in the Bean Creek and Smith Creek drainages; however, these soils formed at lower elevations and a less intense drainage system developed.

Soils on or near the flanks of the volcano had developed in coarse ash or glacial outwash materials. Slopes were gentle and drainage development was minimal.

Most pummice soils are easily moved upon exposure to raindrop impact or channelled water. Individual soil particles tend to be relatively large, light, and easily detached.

Forest productivity for most soils within the devastated area was moderate to low. Site indices ranged from 90 to 100 for Douglas fir and 70 to 80 for western hemlock (both 100 year base) 1/. Soils on the flanks of the volcano and in the Mt. Margaret alpine country were essentially nonproductive.

For more specific descriptions of preeruption soil conditions, the following references should be consulted:

- Soil Resource Inventory - Gifford Pinchot National Forest, USDA Forest Service, Portland, OR 1971.

- Skamania County Soil Survey - USDA Soil Conservation Service, Spokane, WA. (in press).

1/ Data provided by Washington State Department of Natural Resources, Private Forest Land Grading Program, Olympia, WA.

III. THE VOLCANIC EVENT

A. Geologic Setting - Mt. St. Helens is located within the volcanically active High Cascades province of Oregon and Washington. This area contains twelve major volcanic peaks. Several have been active within the past 200 years. Mt. St. Helens has been the most active and explosive of these volcanos. It has erupted repeatedly during the past 2,500 years, discharging pumice, pyroclastic flows, lava, and emplacing lava domes. The most recent activity occurred between 1830 and 1860.

The geologic sections of the watershed areas are characterized by a predominance of volcanic rock. These deposits consist largely of basaltic and andesitic lava flows, pyroclastic and mudflow deposits, and interbedded volcanic breccias and tuff units. Local intrusive rocks comprise Mt. Margaret and other minor peaks.

Previous Mt. St. Helens eruptive events have produced thick deposits of ash and pumice on the mountain flanks, adjacent drainages, and gentle topographic surfaces. Flank lava flows and pyroclastic and mudflow deposits have also modified the previous geomorphic features. Spirit Lake was formed by the damming of the upper North Toutle drainage by such deposits. Portions of the Muddy, Pine, and Lewis drainages show the effects of repeated volcanic deposition and revegetation. Ash and pumice fall deposits are common in the broad valleys of all major drainages in the study area.

B. Eruption Chronology - The present period of activity commenced with a series of seismic events, the first of which was detected on March 20, 1980. Over 3,000 earthquakes ranging from magnitude 3 have occurred to date near the mountain. The following chronology of eruptive events illustrates the subsequent volcanic activity:

March 27, 1980 - The first surface eruption of ash and vapor occurred on the mountain summit. A summit crater was created and slowly enlarged by minor eruptions through April 18. Off-site effects were minor ashflows on the upper mountain and light ashfalls to the south and east of the peak.

April 18, 1980 - Eruptive activity diminished to a low level of gaseous emission. Seismic activity also decreased to magnitude 1 events.

May 7, 1980 - Eruptions of ash and gas increased from the summit crater with off-site effects similar to the March-April period. Significant uplift of the upper north quadrant of the mountain was observed.

May 14, 1980 - Eruptive activity again diminished to a minimal level.

May 17, 1980 - Seismic activity sharply increased.

May 18, 1980 - A 5.1 event immediately preceded a massive failure of the north summit slope.

May 25, 1980 - A major eruption of ash and gas occurred with heavy deposition of ash size material to the west of the mountain and extending to the Oregon and Washington coastlines. Pyroclastic flows affected mountain flanks above the timberline.

June 12, 1980 - Major eruption of vapor, ash, and gas occurred with heavy deposition of ash and medium sand size material extending southwest from the mountain to the Oregon coast and, to a lesser extent, north to the Puget Sound area.

June 15, 1980 - First observation of lava dome formation within the explosive crater. Dome emplacement reached an areal extent at approximately 1,000 feet by 500 feet and a height of approximately 275 feet.

July 22, 1980 - Major eruption of ash and gas occurred with moderate deposition of ash material to the northeast with light deposition reaching western Idaho. Lava dome was erupted or buried by pyroclastic deposits.

August 8, 1980 - Major eruption of ash and gas occurred with light ash deposition to the east extending to central Washington.

C. The Eruption of May 18 - The volcanic event consisted of the explosive collapse of the upper north quadrant of the mountain above approximately 5,200 feet. The ensuing lateral and vertical eruption of gas and ash removed approximately 1,300 feet of the upper mountain and excavated a breached crater approximately 1.5 miles in diameter by 3,000 feet deep. The volume of material removed is estimated to be 0.75 to 1.25 cubic miles.

The lateral blast of the eruption consisted of the shock wave, a thermal effect, and massive amounts of airborne debris. This phase was directed generally northward through an arc of approximately 120 degrees from northwest to east-northeast. Within this zone, destruction was essentially total to a radius of 8 miles; all vegetation and most of the soil profile was removed from many blast-facing slopes. Beyond this zone and extending to 11 miles east-northeast and 13.5 miles north, old-growth timber was blown down and lesser vegetation killed by the shock wave and/or buried by incorporated airborne debris. Surrounding this blowdown zone is a halo 1 to 2 miles wide within which the thermal effect killed standing vegetation.

Following the explosive collapse of the upper mountain slope, massive amounts of material consisting of ash to boulder size rocks avalanched northward into Spirit Lake and the North Toutle and South Coldwater valleys. This debris avalanche carried down the North Toutle valley 15 miles establishing a distal terminus immediately upstream from the confluence with Hoffstedt Creek. Within this zone all existing facilities and vegetation were destroyed.

The final surface effect of the eruption was the hydraulic mobilization of blast material by snow and ice-melt waters and possibly sieche effects from Spirit and St. Helens Lakes. This caused extensive mudflow deposits in the North and South Toutle drainages and to a lesser extent in the Smith, Muddy, and Pine systems. Mudflows inundated existing vegetation and transportation facilities. Entrained vegetation was deposited in drainage bends and constrictions forming large debris mounds or dams. In the case of the Toutle River, damage extended to the Cowlitz River and to the Columbia River navigation channel. The Muddy River effects extended to Swift Reservior on the Lewis River.

Ashfall deposits resulting from the vertical eruption ranged from heavy pyroclastic deposits on the lower mountain flanks to peripheral accumulations ranging from 1 to 18 inches of ash, sand, and pumice. Heaviest accumulations were in the upper Smith, Bean, and Clearwater drainages, where 4 to 13 inches of material were measured over wide areas. Fallout extended eastward from the Forest into Idaho and Montana with thicknesses ranging from 2 to 3 inches along the axis of deposition in eastern Washington to fractions of an inch in northern Idaho and western Montana.

IV. GENERAL POST ERUPTION WATERSHED CONDITION

A. Physical Condition

1. Vegetation - The above-ground portions of all vegetation in the area of down timber was killed; however, roots and below-ground stems (stolons and rhizomes) are alive and sprouting. Where ash or blast-deposited debris is less than 6 inches deep, new growing tips of Canadian thistle, fireweed, blackberry, thimbleberry, oxalis, sword and bracken ferns, and other vegetation, see Appendix 2, are beginning to appear. Canadian thistles appear to be forming new roots in the nearby deposited ash layers. No vegetation was observed to be sprouting through deposited layers deeper than 8 to 10 inches.

Most woody vegetation in the area of standing dead timber appeared to have been defoliated but not killed. Vine maple and alder were observed to be sprouting from the lower foot of stems more than an inch or two in diameter; salal and Oregon grape were found sprouting from root collars. Douglas-fir and hemlock saplings 5 to 8 feet tall that had lost all old needles to the heat, sprouted new growth from undamaged buds. Vegetation that was protected by snow cover was observed growing vigorously in rills or gullies in volcanic material 15 to 18 inches deep. No vegetation was observed germinating on or penetrating undisturbed volcanic deposit.

The blast and shock wave tended to follow drainages at the boundary of the damaged area. Down timber, therefore, frequently lies parallel to the contour. Nearer the crater, stems were generally found to lay parallel to the blast direction and may be either parallel or perpendicular to the slope.

Organic debris covers most of the surface of Spirit Lake and spans all streams wherever blowdown occurred or is mixed with volcanic debris in most stream beds where pyroclastic or mud flows occurred. Most streams contain examples of both conditions.

2. Wildlife, Streams, and Lakes - The fish and wildlife habitat within the blast and mudflow areas has been badly damaged or destroyed. Few, if any, representatives of the original mix of species survived.

Wildlife habitats in the upper reaches of the North and South Toutle and Muddy River drainages were severely damaged, and for the most part were completely altered by heavy depositions of volcanic debris. Habitats within these drainages prior to the eruption supported a broad spectrum of birds, reptiles, and mammals. The eruption and alteration of habitat has left these drainages in a condition where very few wildlife species that inhabited them prior to the eruption can survive. Portions of the Green River drainage and lower reaches of Bean, Smith, and Clearwater drainages were on the fringes of the blast area, but received heavy ash fallout. Wildlife habitats within these drainages, or portions thereof, were altered also. However, they will recover at a faster rate than drainages receiving volcanic deposition and mudflows.

Four hundred and forty-nine miles of stream habitat on National Forest land within the blast and mudflow areas were impacted:

	Stream Classes		
	I & II	III	IV
	-------Miles-----		
1. Destroyed (mudflow)	28	7	65
2. Severe Damage (blast)	9	8	35
3. Heavy Damage (blast and heavy ashfall)	40	62	195

Of these miles, 8 miles were anadromous fish streams, while some 77 miles of stream supported resident trout.

One hundred miles of physical stream habitat were inundated by mudflows and completely destroyed. Mudflow impacted streams will be the last to recover as stream channels, and riparian ecosystems will have to reestablish. Streams in the blast and ash fall areas were impacted by organic debris and ash, but should recover more quickly.

On and off-Forest impacts to anadromous and resident fishery habitat will continue due to increased runoff, peak flows, and surface and channel erosion. Effects of the volcanic activity on salmonid production can be summarized into three broad areas: migration and spawning, and rearing habitat.

Migration routes off the Forest for adult salmonids in the Lower Toutle River drainage are blocked with accumulations of organic debris, ash, and mud; while on the Greenwater, migration barriers are not complete, yet will impact fish movement. Production in the Upper Toutle River drainage for anadromous fish will be eliminated until passage, spawning, and rearing habitat have been established. Migration on the remainder of streams within the blast area on the National Forest is of concern, but not as critical because they do not support resident salmonids.

The entrapment of organic debris in spawning gravels will create low dissolved oxygen levels and reduce reproductive success. Entrapment of ash materials will reduce the intergravel flow of water, and further reduce spawning gravel quality. Salmonid reproductive success will be lost for decades in streams affected by mudflows and reduced for several decades in streams which received ash deposition.

Rearing habitat was lost in those streams inundated by mudflows and severely impacted in streams in heavy ashfall drainages. The losses of riparian habitat will also impact rearing capability. Riparian habitat will recover at a faster rate than the pool habitat in drainages impacted by ashfall. Rearing habitat in the Yakima and Wenatchee Rivers was also affected by ashfall, but impacts will not be as severe as within the heavy ashfall drainages.

Lakes within 12 miles of the initial eruption in a north to northeasterly direction from the crater were severely damaged. Timber surrounding the majority of these lakes was blown down and/or seared by the initial blast. Downed timber has contributed a great amount of organic debris to all lakes. Ground vegetation surrounding the lakes was seared or buried by ashfalls. Water color in most of the lakes ranges from brown gray to almost black, apparently caused by leachates from downed timber. The lake bottom composition varies from an ash-mud mixture in lakes receiving only an ashfall to a dark brown ooze in those lakes also containing downed timber. Very little life was observed on lake bottoms. Very few aquatic insects were found on the lakes. No fish were found in any of the lakes visited in the blast area.

There are approximately 16 lakes in the severely damaged category, the largest being Spirit Lake. Spirit Lake is about 80 percent covered with organic debris, and has a strong odor. Many of the lakes are from 3 to 8 acres in size. New lakes are being formed in tributary drainages on the North Fork of the Toutle. These lakes will range from 2 to 3 acres up to several hundred acres when they have filled after fall and winter rains. Other lakes in a north-northeasterly direction fared much better. These lakes are anywhere from 28 to 40 miles north of the mountain. The only noticed difference from a preeruption condition appears to be the ash deposition on the lake bottoms.

3. Hydrologic Conditions - Past measured peak stream flows have ranged from 50 to 159 c.s.m. Winter flood peaks in the devastated area are predicted to be from 1 to 20 times higher than in the past, depending on the extent of damage. See Appendix 3. Historically, most of these flow peaks occurred in late December or early January following a rain-on-snow situation.

During the eruption on May 18, measured flow from the Muddy River and Pine Creek, based on changes in the level of Swift Reservior, exceeded 60,000 c.f.s. from 9:00 to 10:00 a.m. and dropped to 12,000 c.f.s. from 11:00 to 12:00 a.m..

Most of the deposited material in the stream channels appears easily erodible. It is expected stream channels will be quite unstable and, where not confined, will meander laterally over the stream bottoms.

Measured streamflows in the area on July 8 and 17 varied from 7 c.f.s. to 60 c.f.s. on the Green River and South Fork Toutle River, respectively. These are small flows compared to those expected this winter, so channel erosion and sediment transport will be much greater than that already experienced.

The most critical runoff problems will occur in the heavy blast area where soil has been blown away, reducing the profile water-holding capacity. Conversely, ash deposits overlying undisturbed natural soil may provide increased water-holding capacity if infiltration rates have not been reduced.

Snowmelt will be accelerated due to shade removal which will increase solar radiation and wind movement causing higher peak flows. Normally, the most critical elevations will be between 2,000-3,500 feet elevation.

Glaciers will slowly begin to reform on the mountain. Until they do, a higher than normal melt rate is expected from the snowfields on parts of Mt. St. Helens previously occupied by glaciers. However, these changes in melt rate on Mt. St. Helens may not contribute significantly to peak flows. The most probable impact from the destruction of glaciers will be lower streamflows during the summer low flow months.

Should the future ash eruptions be deposited over an existing snowpack, an increased snow depletion rate may occur. For example, there was a 1 1/2 inch per day water-equivalent loss on one site where a few inches of ash covered the snowpack. Where ash depths exceeded 6 inches, snowmelt appeared to be decreased.

4. Soil Conditions - Recent eruptive activities of Mt. St. Helens have caused several major changes in soil conditions within the devastated area. These include: deep deposition of pyroclastic and mudflow material in major drainages; partial to complete soil removal on some slopes; and deposition of various types and depths of volcanic ejecta over large areas.

In areas of deep (100 to 500 feet) pyroclastic deposition, particularly the North Fork Toutle Valley, soil development will be starting from time zero; primary plant succession will take place over time. Recovery in areas of partial and complete soil removal will also be very slow; again a situation where soil development is starting at time zero.

Greatest impacts on and opportunities for soil management occur in areas of volcanic ash deposition. In most instances, deposited material consists of several layers of differing textures1/. The general layering sequence is a crust of fine ash at the surface overlying a layer of pumice. Below this, a layer of very fine black sand overlies the original soil profile or rock surface. The thickness of each layer varies with location. Pumice layers and thick sand deposits are present only northeast and east of the volcano in the Clearwater, Bean, and Smith Creek drainages.

1/The term "texture" refers to particle size distribution, i.e., the percentage of sand, silt, and clay.

These deposits have significantly affected the manner in which the devastated area handles the precipitation it receives. In layered profiles where textural differences exist, downward water movement may be impeded. Where fine-textured material overlies coarse material, water tends to be bound tightly in the fine material by capillary forces.

Where coarse material overlies finer material, water tends to saturate the coarse material rapidly while water movement into the fines is comparatively slow. These phenomena have important implications in terms of sheet and rill erosion development. It may be possible to saturate an entire layer and have it move downslope as a mass. This was observed on a minor scale in the field.

Field measurements of infiltration rates in ash surfaces indicate them to be low. See Appendix 8. When water is applied rapidly to ash surfaces, it tends to run off. When enough energy is gathered, the surface crust is broken and the water begins to form a channel. Once water is directed into a channel (i.e., rill or gully system) sufficient energy is usually present to keep the channel growing laterally, longitudinally, and vertically.

The impact of accelerated rill and gully erosion on future forest productivity could be great. In all drainages, on steep slopes where vegetation had been removed either by clearcutting or by the volcanic event, rill and gully systems were observed to be downcutting in preeruption mineral soil. In most forested soils, the majority of stored nutrients are located in the top 6 to 10 inches of the profile. By removing large quantities of preeruption soils, forest productivity may be significantly reduced in the future.

5. Erosion and Sedimentation - Measured rill and gully erosion on slopes varied from 5 to 540 tons per acre for a 6-week period. Precipitation during this period was slightly more than 5 inches, a relatively moderate amount compared to an annual precipitation of 140 inches.

Rill and gully development in areas of standing dead and downed timber was observed to be minor. This was particularly true where downed timber was oriented across slope.

Channel and gully erosion has been severe in the unconsolidated pyroclastic and mud flow deposits of the major drainages. Erosion rates vary from 3 to 3,180 acre-feet per mile for the period of May 18 to June 19 (photo flight date). Depth of incision has exceeded 30 feet on sections at the North Fork Toutle River near Castle Creek.

Deposition of eroded material is occurring along the breaks of slope in U-shaped valleys and where stream gradients reduce in broad valley basins. Where ash or mudflows have accumulated in stream bottoms adjacent to steep side slopes, side channel erosion and headcutting have occurred. This is caused by water entering the main stream bottom from steep side slopes without a break in gradient.

6. Slope Stability - An increase in mass movement activity may be encountered in the future in all drainages, particularly in areas where large amounts of timber were blown down and root wads upturned. These areas have almost completly lost their transpiring surface and soil moisture contents will increase. Soils may liquefy in some cases and move rapidly downslope, increasing future sediment loading. Further aggrevating this condition is the deposition of varying amounts and types of ash materials. This material is very unconsolidated and will have a strong tendency to mobilize when saturated on steep slopes; this is particularly true for deep pumice, sand, and pyroclastic deposits during seismic shock.

7. Transportation - Roads within the blast area are covered with 1 to 13 inches or more of ash fallout, while water-concentrated or drifted ash is up to 5 or 10 feet deep in some areas. Many roads throughout the area have been destroyed, obliterated, covered, or breached by pyroclastic flows, debris flows, mudflows, and channeled water.

Road damage is greatest in the direct blast area (North Toutle and Coldwater drainages) and in heavy ash fallout areas (Bean and Smith Creeks). Most roads in these areas are breached and will not interfere with drainage on slopes. Work required to reestablish a transportation system in the devastated area ranges from light ash removal, to moderate reconstruction and culvert replacement, to local relocation and new construction.

8. Physical Properties of Ashfall and Pyroclastic Deposits - The materials are nonplastic silts and sands with 57 to 85 percent and 0 to 22 percent passing the number 200 sieve, respectively. Generally, they have very low densities inplace with moderate to low permeabilities; clean pumice deposits have high permeabilities.

Corrosion of buried metal structures will be severe to very severe due to the moderate pH (5.3 to 6.7) and the low resistivity (700 to 1,700 ohm-cm) in the finer ash materials.

Measured shear strength friction angles of 4 to 8 degrees are lower than expected for the material tested. The moderate to high apparent strength in the field will be lost when the finer ash layers become wet.

The combination of low density, low strength materials, on steep slopes with high rainfall will result in much downslope movement of the ash by erosion and mass wasting.

B. Conclusions - Conclusions are presented in portions of this report devoted to specific drainages.

C. Recommendations - General recommendations apply to all drainages unless the specific recommendations make exceptions.

1. Salvage Logging - The objectives of this general timber salvage recommendation will be to protect life and property downstream, maintain site productivity, and recover salvageable timber volume, in that order.

When timber salvage is planned, the following criteria are recommended:

a. Logs spanning stream channels should be removed first. Those in channels which may contribute to channel damage at times of high stream flow should have the above ground portions removed.

b. Standing dead timber is second priority for salvage. Ground vegetation was least damaged in these stands and will recover first to protect soil. Also, tree roots are still in place to hold soil. Dead needles and fine branches remaining on standing trees will contribute greatly to fire hazard. Obviously, distressed live trees should be removed as their probability of recovery is small. It may be necessary to leave some standing timber to meet Regional policy on snags and streamside management.

c. Down timber should be salvaged last to give more severely damaged ground vegetation a chance to recover, and to capitalize on short term sediment trapping. This is important since many tree roots have been pulled out leaving nothing but down timber to hold soil and reduce erosion.

d. During salvage logging, cull material should be arranged as log terraces parallel to the contour to serve as debris dams. See Appendix 4. Merchantable logs or silt fences should be used if cull material is not available. This practice will help preserve site productivity and reduce erosion. Cull material should be anchored behind stumps or rocks where possible. Where dense down timber was found parallel to the slopes, it appeared that as much as 75 percent of the surface erosion was trapped.

e. Logging systems which provide for one-end suspension of the log should be used to break up the ash surface and facilitate recovery of ground vegetation. We have conflicting objectives here that must be reconciled because both surface disturbance and surface stabilization are necessary. This need makes snag terraces very important.

f. The prescribed seed mix should be sown at 6 to 8 pounds per acre following salavage in areas where natural vegetation is not recovering.

g. Salvage logging should be timed to (1) minimize downstream impacts to other resources, and (2) allow establishment of seeded annual grasses before snowfall.

2. Transporation Systems - The road system in the devastated area generally has been buried or cut by gullies when drainage systems became plugged. In some instances, ash deposition has formed a protective cover. This cover should not be disturbed and roads should not be opened until they can be continuously maintained.

a. When building, reconstructing, or repairing roads, use fords, dips, or outsloping, where feasible, when there is a potential threat of culvert or bridge failure due to plugging with sediment or debris.

b. Use portable or removable bridges on major streams where fords are not appropriate and where there is high potential threat for culvert or bridge failure due to plugging with sediment or debris.

c. Where accessible for maintenance, install trash racks above major existing culverts or bridges where a high potential threat of watershed drainage from culvert or bridge failure exists.

d. Increase road maintenance frequency in ashfall areas.

e. When reopening roads in the blast area, increase the size and decrease spacing of ditch relief cross-drain culverts to handle (1) more runoff, (2) more sediment, and (3) larger debris.

f. Design for new culverts should recognize the increased peak flows and high sediment load. See Appendix 3 for peak flow.

g. Open heavy ash covered and breached roads in the blast zone only as they are needed.

h. Design and select buried structural materials to withstand very severe electrolytic corrosion. See Appendix 8.

i. When clearing roads of ash, pumice, and sand deposits, follow the recommendations in Bill Powell's letter (7170, August 6) to Ed Gililland on "Tephra Removal." See Appendix 10.

3. Monitoring, Evaluation, and Studies - Because of the uniqueness of the eruption, there is much that is not known. For example, erosion rates, sediment movement and transport, water quality recovery, pyroclastic flow and ashfall behavior over time, vegetative recovery, stability of dams, snow ablation, and a host of other items should be monitored, studied, and evaluated.

Administrators need answers to many new questions to deal effectively with rehabilitation efforts for problems that either exist currently or will occur in the future.

Following is a subject-matter list of topics that should be monitored and/or studied to determine the effectiveness of this team's recommendations and to form a basis for dealing with future volcanic activity on Mt. St. Helens.

a. Sedimentation deposit rates behind impoundments.

b. Gully and channel erosion rates.

c. The rate of sheet erosion.

d. Reestablishment of vegetation.

e. Recovery of wildlife and fish habitat.

f. Stream and lake hydrology.

g. Ground water discharge rates.

h. Geomorphic modification rates.

i. Suspended sediment values.

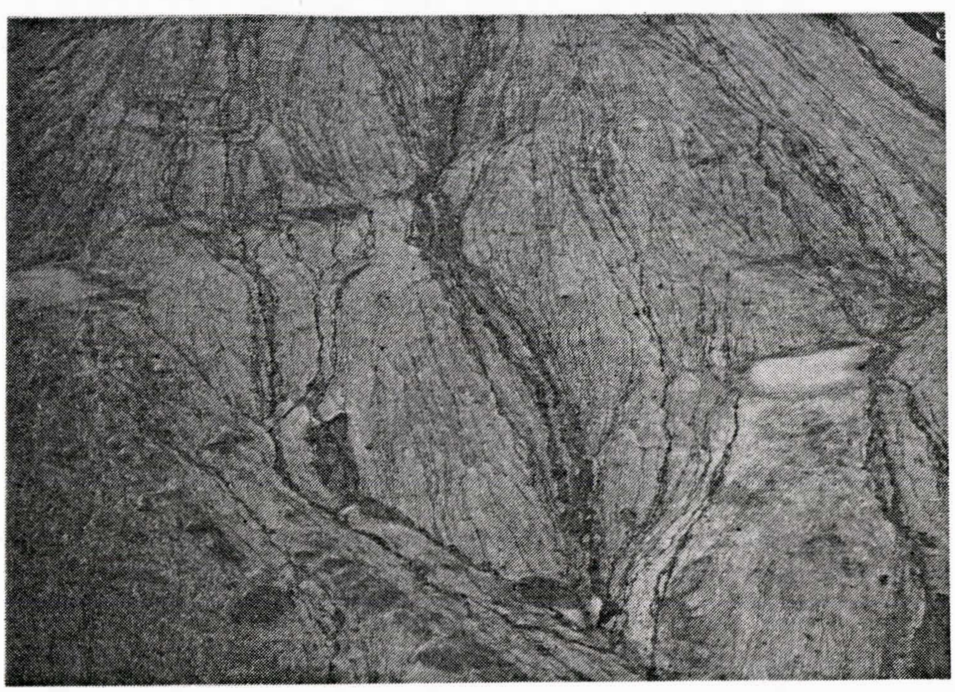
This list is not meant to be all inclusive. Many agencies will have their own ideas about which factors should be monitored or studied. Coordination among agencies to avoid duplication will be very important.

The Forest should develop a flood warning procedure and action plan specifically for the eruption area on National Forest land utilizing other agencies' data and technical assistance where possible. This should be done prior to the time capital investments are made, or activities that might need protection are conducted, in the area.

Development of such a warning system may require the Forest Service to install instrumentation such as rain gages, stream gaging stations, snow courses, etc., which would be supplemental to and coordinated with other agencies' plans. The tentative hydrometeorological stations planned by other agencies are contained in Appendix 3.

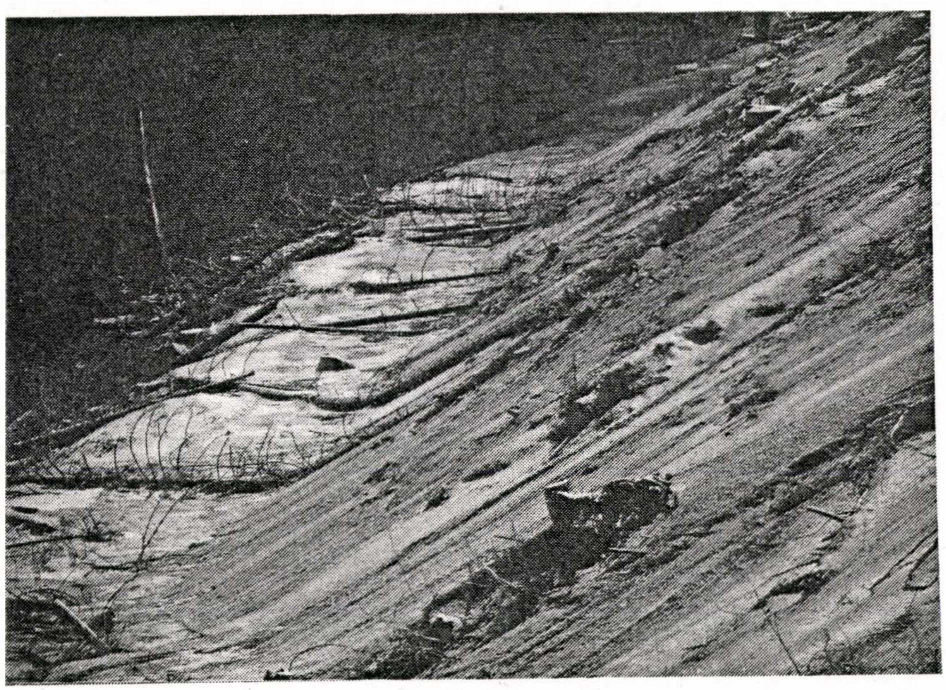
A significant part of monitoring should be the overall evaluation of the conclusions and recommendations in this report. The entire Emergency Rehabilitation Team should return to the area in June 1981 to evaluate and critique this report.

Mt. St. Helens and Spirit Lake viewed from the north showing pyroclastic deposition and new shoreline.



Extreme rill and gully development along the east arm of Spirit Lake.

Potentially salvageable down timber. Although potentially salvageable, much down timber is providing an effective barrier to surface erosion.



Transportation facilities have been impacted by ash deposition, erosion and blockage by down timber.

V SPECIFIC POSTERUPTION CONDITION

Elements of the watershed discussed in the general statement also have unique conditions that must be discussed by drainages. Specific conclusions and recommendations relating to those conditions will be addressed by drainage in the following sections.

A. North Fork Toutle River Drainage

From Spirit Lake to the confluence with Coldwater Creek,
plus Coldwater Creek and South Coldwater Creek,
Castle Creek, and Spirit Lake basin (20.34 square miles).

1. Geologic Condition

a. Blast Effects - Volcanic modification of this system by the May 18 and subsequent eruptions has been the most severe of all the watersheds. Destruction of the upper north quadrant of the mountain was oriented directly toward the upper North Fork Toutle River and Coldwater Creek drainage systems and Spirit Lake basin. The collapse and explosive eruption of the north face formed a breached crater and depositional ramp directed toward the drainage system. This structural orientation has channeled subsequent eruptive activity into the Spirit Lake basin and upper portion of the North Fork Toutle River.

Swash lines indicate that the water of Spirit Lake was forced upslope in the north and east arms to elevations several hundred feet above previous levels, stripping soil to bedrock and depositing upslope debris upon retreat.

b. Deposition Effects - Topographic modification was extensive in this drainage. This was caused by the avalanching of landslide and pyroclastic debris from the north mountain face; the deposition of mudflow debris from melting snow and ice, and probably backwash from Spirit Lake, and deposition of airborne material.

The deposition of pyroclastic material in the upper North Fork Toutle River exceeds 500 feet in depth near the previous location of Spirit Lake Lodge. This deposit extends down the North Fork Toutle River to the vicinity of Hoffstadt Creek. The thickness decreases downstream with the following values:

320 feet of deposition at Studebaker Creek,

240 " " " " Coldwater Creek,

240 " " " " Jackson Creek,

40 " " " " Bear Creek with

distal terminus at Hoffstadt Creek.

During down valley movement, material was forced laterally into side tributaries. As the peak debris flowed passed, shear features were developed along the North Fork Toutle valley margins. These shear moraines and the mounding of material in the tributaries form natural dams which block Jackson, Elk, Coldwater/South Coldwater, and South Fork Castle Creeks. The impoundment capacity behind these structures is significant at South Fork Castle Creek (approximately 17,500 acre-feet) and Coldwater/South Coldwater Creeks (approximately 171,000 acre-feet). Table 1 in Appendix 7, gives further structural and hydrologic data. See Appendix 9 for stability analysis.

The maximum deposition at the outlet of Spirit Lake has dammed the basin to an elevation of 3,565 feet above mean sea level and created additional storage capacity of approximately 440,000 acre-feet. Present lake level elevation is approximately 3,407 feet above mean sea level as of the date of supplemental USGS topography.

Material comprising the pyroclastic flow is a heterogenous mix of ash to large boulders. The predominant material fraction classifies as gravelly sand (USCS: SP-SMd) with 10 percent passing the 200 sieve. From exposed faces on the flow surface near Coldwater Creek dam, the overall size distribution was estimated to be: boulders over 24 inches in diameter - 20 percent, cobbles and boulders 6 inches to 24 inches in diameter - 20 percent, and material less than 6 inches in diameter - 60 percent. The fines were tested and found to be nonplastic.

The upper surface of the pyroclastic flow varies from water deposited features near Spirit Lake, to areas of extreme hummocking where the valley gradient steepens. Relief in these areas reaches 50 to 100 feet with frequent interior drainage basins several hundred acre-feet in capacity. Near the upper terminus of the flow at Spirit Lake numerous explosion craters exist as the result of the vaporization of ground water and ice by hot avalanche material.

The valley walls show specific features documenting the magnitude of debris movement. Of particular significance is the area between Spirit Lake and Spirit Lake Lodge. Here remnants of the pyroclastic flow exist up a drainage and through the saddle into South Coldwater Creek drainage, indicating that the initial surge of material overtopped this 1,000-foot ridge. Numerous other scour features indicate maximum deposition levels as the flow moved down canyon. Further indications of depth of flow are the numerous "perched deposits" of pyroclastic material that exist along the north canyon wall between Spirit Lake and Coldwater Creek. Thousands of cubic yards of material exist in these perched positions.

Deposits of airborne debris (boulders and large soil masses) exist in the upper Coldwater Creek drainage, on Mt. Margaret, and on northward extensions of Spirit Lake. This type of deposit forms the hummocky terrain features in upper Bear Creek.

Two additional depositional mechanisms were active within this drainage system. Ashfall deposits cover much of the drainage area with varying thicknesses of material. Maximum ashfall varies from 2 inches (2" ash-ML) in Coldwater canyon to 8 inches (8" ash-ML) in Jackson canyon to 48 inches (48" ash-ML) near the southwest corner of Spirit Lake. Mudflow deposition has occurred on the pyroclastic flow and within the side drainages. Here, material of the pyroclastic flow and ashfalls has been saturated and remobilized by precipitation, snow/ice melt, or possibly lake surge, and transported downslope. The most significant deposit of this type occurs in the North Fork Toutle River below the distal terminus of the pyroclastic flow. Other significant depositions of this type have occurred behind the Castle Creek and Coldwater Creek structures and on the pyroclastic ramp from the crater to Spirit Lake.

2. Vegetation and Debris - Pyroclastic flows have no living surface vegetation, and their depth precludes sprouting of native vegetation.

South facing slopes immediately above the North Fork Toutle River which were not snow covered at the time of eruption, were denuded. In many areas on these slopes, much of the soil mantle, containing root masses, was blown away, exposing bedrock. This is particularly true on the upper one-third of the slopes. In these areas, there is no subsurface material available for resprouting even though ash deposits are only 1 to 2 inches.

On the north-facing leeward slopes, both perennial herbaceous materials and shrubs are resprouting. These plants are pushing through 2 to 4 inches of ash. It is anticipated that many of these plants will mature and produce seed this fall. This should provide additional plant cover in the coming year, particularly where native soil can be reached. On a west slope in Coldwater Creek, seeds were observed germinating in original soil along rills which had cut through ash deposits.

The Coldwater Creek drainages, blocked by the North Fork Toutle River pyroclastic flow contain much organic debris. The material is concentrated on north facing slopes in the Coldwater Creek drainage and surrounding Spirit Lake. Organic debris covers Spirit Lake and is present to some degree at numerous places in the North Fork Toutle River. The material in the North Fork Toutle River is outside the Forest. No undamaged standing merchantable timber was observed.

3. Wildlife Streams and Lakes - Fish and Wildlife habitats within the upper reaches of the North Fork Toutle River were severely damaged and completely altered by the blast and deposition. The eruption and alteration of habitat has left a condition in these drainages where very few, if any, wildlife species that inhabited these drainages did or can survive.

Pyroclastic flows buried the North Fork Toutle anadromous stream. Losses of fish habitat on National Forest land are substantial. Off-Forest impacts to fish hatchery facilities on the Toutle River, and to anadromous fish production, are of regional significance.

Spirit Lake was severely damaged. The total physical characteristics have been altered. The lake surface is now 269 feet higher than preeruption elevations. Heavy woody debris covers 80 percent of the lake surface.

4. Hydrologic Condition - This drainage basin was the most severely damaged from a hydrologic viewpoint. Most of the area has little ground cover and some slopes are down to bedrock. Entire drainage patterns were even altered.

Peak runoff per unit of area will be the highest of any of the basins. See Appendix 3. There may be some dampening effect to these peak flows in the main North Fork Toutle valley because of the deep deposits of pyroclastic flow which may act as a "sponge" at certain times of the year.

With much of the sediment currently in the stream bottoms, very high sediment transport is expected due to the accelerated flows.

Many of the pyroclastic flows appear to have a high turbidity potential, so it is expected that they will continue to "bleed" high turbidities during rainfall events for some time until vegetative ground cover is reestablished.

The Coldwater Creek subbasin is expected to have the highest peak runoff per unit area because of the very steep slopes in the headwaters and lack of cover.

The closed basins of Spirit Lake, Castle Creek, and Coldwater Creek will prevent 61 percent of the annual runoff from advancing down the North Fork Toutle River.

5. Soils - Soil conditions within these drainages have, in many locations, been severely altered from the preeruption state. The ramp extending from the crater to the shore of Spirit Lake, the pyroclastic flow in the North Fork Toutle River valley, the pyroclastic flow deposits up and over the ridge between the North Fork Toutle River and South Coldwater Creek drainages, and at the north end of Spirit Lake all consist of new volcanic deposition. In all these areas, new soil development will be very slow.

Slopes on southeast aspects in the North Fork Toutle River, South Coldwater Creek, and Coldwater Creek drainages which were in direct line with the lateral blast have had much of the original soil material removed and deposited elsewhere. It appears from field and aerial photograph observation that much of this material was redeposited on leeward slopes. Extensive rill and gully systems have developed in these areas. Measured rill erosion in the South Coldwater Creek drainage on July 10 (60 percent slope) ranged from 57 to 144 tons per acre. One transect was measured on a road and a figure of 540 tons per acre was obtained.

Drainage bottoms in both Coldwater and South Coldwater Creeks have been inundated either by pyroclastic flow material or by alluvial material from upper slopes and associated woody debris.

Spirit Lake basin has been greatly altered. The splash wave which swept across the lake at the time of the May 18 eruption washed nearly all soil from the slopes at the north end. Much soil material was redeposited on the upper slopes near Mt. Margaret. At the upper end of Bear Creek there is nearly 18 inches of newly deposited material on the gentler slopes while there is only 1 to 2 inches on the steeper slopes.

Most slopes within these drainages have been completely denuded of vegetation. There is the possibility of increased mass wasting activity in the future, particularly where pyroclastic flow material has spanned ridge systems.

Ash deposition within these drainages is highly variable. On the pyroclastic flow near South Coldwater Creek deposits consist of 1/2 to 1 1/2 inches of fine ash. In the South Coldwater Creek drainage, deposits consist of 1 to 2 inches of fine ash. At the mouth of Jackson Creek, deposits consist of 6 to 8 inches of fine ash.

The overland sediment delivery estimate from each subbasin is as follows:

Coldwater Creek and South Coldwater Creek	801 acre-feet
Spirit Lake	1129 acre-feet
Castle Creek	612 acre-feet

The derivation of these values is in Appendix 5.

6. Channel and Gully Erosion - Channel and gully erosion are the significant posteruptive effects within the North Fork Toutle River system. Dissection of the pyroclastic flow by stream action has been rapid and severe. Head cutting has advanced upflow from the distal terminous to the confluence of Castle Creek and has reached depths in excess of 50 feet along mainstream gullies. Calculated erosion rates for this area range from 100 acre feet per mile near Spirit Lake to 3,180 acre-feet per mile in the vicinity of Bear Creek. The adjusted annual sediment yield from gully and channel erosion from the total pyroclastic flow section is 70,000 acre-feet per year. These rates are expected to increase as the drainage system is established on the pyroclastic flow and begins to dissect these deep erodible deposits and bank failure increases. Channel and gully sediment delivered to Castle Creek, Coldwater Creek, and Spirit Lake basin will be trapped by the existing natural dams. Volumes so controlled are calculated to be 300 acre-feet per year in Castle Creek, 1,700 acre-feet per year in Coldwater Creek, and 465 feet per year in Spirit Lake.

Stability of slopes in the North Fork Toutle River system are critical. On the pyroclastic flow, the potential for bank failure must be considered extreme due to the material size (USCS-SMd) and nonplastic nature. Extensive failure has already occurred in areas where channel incision exceeds 20 to 30 feet in the lower flow area. Significant slope failure of pyroclastic material perched on upper slopes and of ashfall material has also occurred under minimal precipitation and runoff conditions to date. Stability conditions on the crater ramp and volcano flanks have not been assessed. However, with thick deposits of unconsolidated and nonplastic material they must be considered to have marginal factors of safety.

Ground water conditions in the North Fork Toutle River system depend to great extent upon two factors. These are (1) the permeability and porosity of the pyroclastic flow and the (2) extent to which original stream gravels were preserved during burial. Porosity values (n) of pyroclastic material are on the order of 0.18 (1 test). Permeability values are on the order of 1.6 x 10-2 cm/sec for SP-SMd material (1 test). Reservoir capacity for groundwater of the pyroclastic flow is estimated to be 300,000 acre-feet.

The effect of buried alluvial gravels must be considered with respect to reservoir integrity of Castle Creek, Coldwater Creek, and Spirit Lake structures. This effect, however, can only be inferred at this time due to complete lack of direct evidence. If original gravels were buried intact beneath the pyroclastic flow, then aquifers may exist beneath the Castle Creek, Coldwater Creek, and Spirit Lake structures. These aquifers, until silted, could significantly effect the retention rates of the structures.

7. Transportation System - Roads in the North Fork Toutle valley bottom are completely destroyed and covered by pyroclastic flow material, cutting off primary access to National Forest lands on the north side of the valley. Road N928 in South Coldwater Creek is inaccessible and heavily covered with ash and debris. Road 1002 on the north rim of Coldwater Creek canyon near Hanaford Lake is heavily damaged by ash deposits and erosion. The road could be made accessible from the Green River drainage via roads on private land to the west. These roads are in the direct blast area and would require extensive reconstruction.

Most roads in the area have been breached or blocked by ash deposits, water erosion, or mud and debris slides. Road deposition is so extensive that the roads are not a barrier to downslope movement of surface runoff.

8. Conclusions

a. This drainage exhibits the widest range of volcanic phenomenan resulting from the eruption, explosive blast, and subsequent deposition, flows, and erosion of all the drainages observed.

b. Observed variation in water levels of Spirit Lake, explosion craters, and natural depressions indicates very slow ground water transmission rates.

c. Future eruptions will subject the crater ramp and south shore of Spirit Lake to continued pyroclastic flow deposits.

d. Vegetative recovery will progress faster on lee slopes which were relatively protected from the blast effects.

e. Blast exposed slopes where soil was removed will be very slow to recover.

f. Vegetation is recovering most rapidly on areas that were snow covered prior to the eruption and where rills have exposed the original soil surface and where ash depths are thinnest.

g. Revegetation of the crater ramp will be restricted by pyroclastic flows and ashfall deposits of continuing eruptions.

h. Significant amounts of woody debris will accumulate in the South Castle Creek and Coldwater Creek impoundments.

i. Woody debris remaining on the slopes of Coldwater Creek drainage will reduce erosion.

j. Sixty-five percent of the drainage area on National Forest land and 37 percent of the sediment yield is controlled by Spirit Lake, Coldwater Creek, and South Castle Creek natural dams.

k. Peak flow hydrographs will not significantly decrease over the immediate future.

l. Because of the storage capacity (22,000 acre-feet) and inflow potential (average annual 14,900 acre-feet), the natural impoundmeant of South Castle Creek could overtop during the winter of 1980-81.

m. Spirit Lake and Coldwater Creek impoundments will not overtop the first year unless erosion or structural failure causes breaching.

n. Natural impoundments of Spirit Lake, Coldwater Creek, and South Castle Creek have the capacity to store the predicted sediment delivery for the respective drainages.

o. Natural dams on Coldwater and South Castle Creeks are formed of low density deposits which are subject to collapse and liquefication during earthquakes. Risk will increase as lakes fill.

p. Filling and overtopping of South Castle Creek impoundment will cause severe downstream erosion and sediment deposition.

q. The channel and gully system developing on the pyroclastic flow will advance rapidly upstream causing widespread dissection and heavy sediment contribution. All natural impoundments will ultimately be imperiled by this process.

r. Sediment yield in this drainage will be predominantly from gully and channel erosion of the pyroclastic flow.

9. Recommendations - North Fork Toutle River System - These specific recommendations are in addition to those in the General Section.

Pyroclastic flow and Spirit Lake basin.

Short Term:

a. Seeding of the pyroclastic flow will have little effect in reducing gully and channel erosion and hence will provide no significant downstream sediment reduction benefits. Seeding of the crater ramp is exposed to pyroclastic flow activity. Seeding is not recommended.

b. Spirit Lake basin is controlled by the pyroclastic dam hence produced sediment will be trapped. Seeding is not recommended.

C. Complete additional structural evaluation of natural impoundment including:

(1) Groundwater transmission.

(2) Embankment stability.

(3) Downstream gully advance hazard.

Long Term:

a. Monitoring of the following is recommended:

(1) Lake water surface level.

(2) Gully and channel erosion rates, especially as they approach dam.

(3) Seepage rates through or around impoundment structure.

Coldwater Creeks

Short Term:

a. Install an automatic warning system for potential dam failure.

b. Monitor lake level starting immediately.

c. Retain woody debris for all slopes to protect reestablishing vegetation from erosion. Debris will not be a downstream hazard due to natural impoundment.

d. Establish ownership and structural liability for natural impoundment structure.

e. Complete additional structural evaluation of natural impoundment including:

(1) Foundation evaluation.

(2) Groundwater transmission.

(3) Embankment stability.

(4) Reservoir and drainage hydrology.

(5) Sediment retention rate.

(6) Downstream gully advance hazard.

Long Term:

a. Monitoring of the following is recommended.

(1) Lake water surface level.

(2) Gully and channel erosion rates, especially as they approach dam.

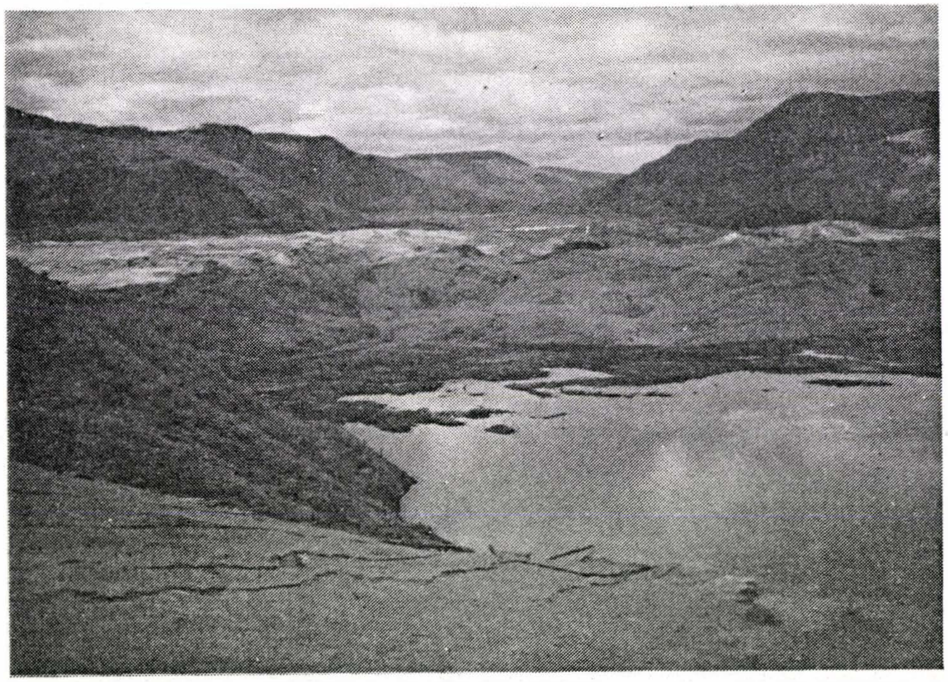
b. No long term management recommendations are made due to the controlled nature of the drainage.

South Castle Creek

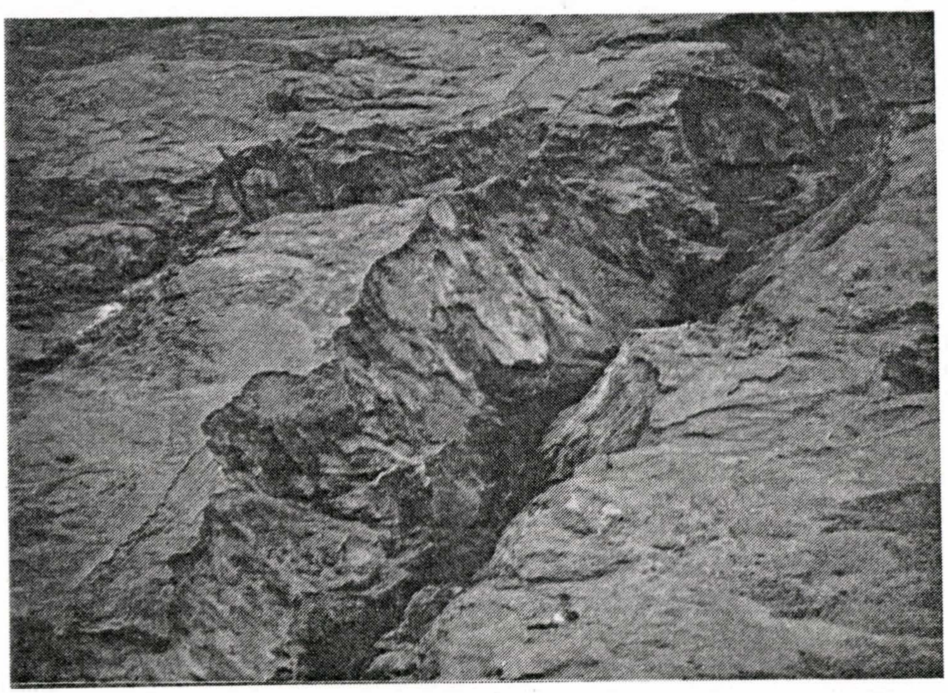
Short Term:

a. Ownership and structural liability for the natural impoundment should be established.

b. Due to the potential for overtopping of the structure during the 1980-81 winter period, it is recommended that further analysis of downstream effects should be performed and, if then warranted, either breaching or protection of the structure be accomplished. This structure is not on Federal land. Breaching must be coordinated with owner.



Pyroclastic flow material in the North Fork Toutle drainage blocking Coldwater and South Coldwater Creeks.



Gully advancement and bank erosion in the pyroclastic flow has been rapid.

NORTH FORK TOUTLE RIVER

COLDWATER CREEK

SPIRIT LAKE

B. GREEN RIVER DRAINAGE

Headwaters to the Forest boundary
including all side drainages (38.37 square miles).

1. Geologic Condition

a. Blast Effects - Although severe in localized areas, the overall blast effects upon the Green River system are less than most other systems in the eruption area. Most heavily impacted are the headwaters of Grizzly Creek and the northern Mt. Margaret lake country. Damage ranges from complete soil and vegetation loss in the high peaks area to the halo zone where vegetation was killed by thermal effect but left standing. The majority of the system was affected by severe timber blowdown. Numerous examples of topographic effects on blast propagation are recorded in this system by blowdown patterns, leave areas, and the thermal halo effect. Significant amounts of airborne debris were deposited on the lee slopes of the upper lake drainages.

b. Depositional Effects - Depositional effects in the upper headwaters and lake country of this system consist primarily of airborne ashfall deposits. Thicknesses vary from 3-1/2 inches (2-1/2" ash - ML, 1" sand - SMd), near where the Green River crosses the Forest boundary to 4 inches (4" ash - ML) in the upper drainage near Last Hope Mine. Mudflow deposits which are thought to have originated from rapid snow melt during the eruption have moved down the upper Green River, Grizzly Creek, and Miners Creek and formed alluvial fans in the mainstem drainage.

2. Vegetation Condition - The vegetation of this drainage, exclusive of the coniferous trees, was damaged to a much lesser extent than any other drainage. Ash depths of four inches or less have allowed extensive resprouting. Numerous herbaceous species were observed pushing through the ash, led by oxalis, blackberry, thimbleberry, fireweed, and Canadian thistle. In addition, shrubby species, such as vine maple, salal, and alder were observed resprouting both above ground and from root stock.

This drainage is on the outer limits of the blast area and contains approximately 30 percent standing dead timber. Heavy concentrations of down timber exist on the slopes and channel bottoms. The understory of the standing dead material was top killed by heat and/or gases, but it is rapidly recovering. In addition, the native soil is basically undisturbed, except for the ash layer, which allows reestablishment of these herbaceous and shrub species.

3. Wildlife, Streams, and Lakes - Fish and Wildlife habitat within the basin was altered by the blast and ashfall but, being on the fringe, will recover at a faster rate than North Fork Toutle River, Bean Creek, and Smith Creek.

In the headwaters, 5 to 10 feet of ash (sediment) has already deposited in pool habitat. Within the blast area blowdown spans stream channels in heavy concentrations.

4. Hydrology - The upper Green River basin is in a wide, relatively flat basin with a low stream gradient. Blown down debris across the channel will potentially be moved by high water.

Precipitation and subsequent runoff is less than for other basins. For example, peak flows in the basin will be about one-half of what can be expected in more severely damaged basins.

Water quality in the upper basin should improve rapidly due to the lack of pyroclastic flows in the channel. There is a large undisturbed area of standing green timber adjacent to the Green River which can serve as a buffer strip for reducing sediment and debris in the lower section. It should also cool water temperatures that will rise in the unshaded stream.

5. Soils - Soils existing in the drainage prior to the May 18 eruption have not been altered significantly by volcanic activity. The major impact on soils has been the deposition of volcanic ash.

Recent mass wasting activity (primarily planar failures) was observed on steep slopes near the Black Prince Mine. Well-developed rill and gully erosion was observed on steeper slopes in clearcuts only. Measured rill and gully erosion on July 8 (15 to 20 percent slopes) was 3 to 20 tons per acre. The slope and topography of the drainage basin will aid in reducing sediment delivery to the stream system.

Vegetative recovery in this drainage should be relatively rapid. Potential losses of forest productivity will be low.

The overland sediment yield in this basin is as follows:

Lower Green River	18 acre-feet
Upper Green River	76 acre-feet

The derivation of these values is in Appendix 5.

6. Channel and Gully Erosion - Channel and gully erosion has developed in the ashfall material and alluvial fan deposits. The most severe effects are in the upstream drainage and lake sections where clearcut areas existed or where the severest blowdown occurred. Channel incision varies from 1.5 feet near the forest boundary to 3 to 5 feet in the upper drainages. Calculated erosion rates varied from 5 acre-feet per mile on the lower drainage to 10 acre feet per mile in the upper areas. The adjusted annual sediment yield at the forest boundary from gully and channel erosion is 665 acre-feet per year.

Two possible detention sites were considered in the upper drainage of the system. The storage to inflow ratio of the lower site is 0.094 thus providing a very low sediment trapping efficiency. The upper site has the required capacity for several years of sedimentation, however the cost per acre-foot of storage is considered excessive considering the embankment volume required per acre-foot of storage. See Table 3, Appendix 7..

7. Transportation - The Green River drainage was approximately 75 percent roadless prior to the eruption. Damage to the roads leading into and within the drainage consist of 2 to 4 inches of fine ash, blown down timber, mud and debris deposits on the road, and plugged or eroded drainage ways.

Previously roaded areas can be accessed using the current road system after it is cleaned up. Owners of private land intermixed with National Forest land have accessed the lower Green River area by road.

The bridge near the Forest boundary in section 31 appears safe from debris plugging.

8. Conclusion - These conclusions are based on the preceding situation statements.

a. This drainage is the least damaged basin with a high potential for rapid recovery; therefore, site values should be protected.

b. Sediment yield will be lower than other basins due to the amount of down timber on the surface, the relatively undisturbed surface mantle, and lower ash depths.

c. Vegetative recovery will progress more rapidly than in other basins because of lesser blast effects and ash depths.

d. In the areas of scorched standing timber and down timber with large crowns, there is high fire hazard and related potential for additional resource damage.

e. There is a high potential for localized flood peaks but they will be less per unit area than in other drainages.

f. The downed timber is performing as a very effective sediment trap.

g. Erosion potential is higher on old clearcuts because of the absence of woody debris.

h. The opportunity exists to maintain ash and soil on the slopes to protect relatively high site values.

i. The cost of constructing potential sediment trap structures at two sites on the Green River would be too high for the volume trapped.

j. Woody debris removal from the channel in proposed Management Unit One, down stream portion, is not needed (unless as part of ongoing salvage program) because it presents no significant threat to life, health, or property downstream.

k. Woody debris upstream of standing timber will move with high water and jam up.

l. Removing downed timber along the channel after fall-spring runoff will again impact stream recovery. Removal this fall will prevent potential jams and avoid further disturbance next spring.

m. The road system can be reestablished because of light damage, accessibility, and physical characteristics of the area.

9. Recommendations - Green River Drainage - These specific recommendations are in addition to those in the General Section

Short Term

a. Seed and fertilize (see details contained in Appendix 12).

b. When timber salvage commences, give first priority to standing dead timber in lower Green River to reduce fire hazard.

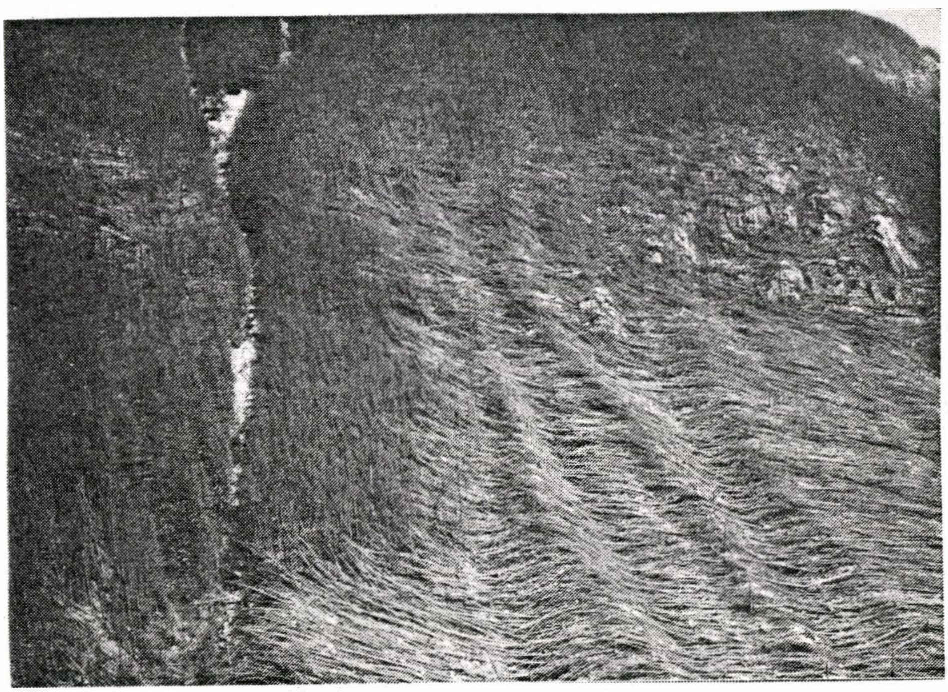
c. Install "silt fences" in the major riparian areas in clear-cut units adjacent to the riparian areas on slopes less than 30 percent where surface erosion will not be trapped by down timber. Silt fences, upon filling, should subsequently be seeded and fertilized to promote stabilization. (For details on spacing, construction, etc., see Appendix 4.)

d. Remove trees and woody debris spanning the stream in the upper Green River that are likely to be moved by peak flows this fall, to avoid further damage to the riparian area. Remove trees within 100 feet of each side of the stream bank or to the height of average flood flows, whichever is greater.

Long Term

a. Plant riparian vegetation (cottonwood, alder, and willow) in the upper Green River basin after salvaging timber, and seed and fertilize such treated areas if not already done in the general seeding prescription.

Woody debris in Green River.



Standing dead and down timber north of the Green River.


GREEN RIVER
Legend
Silt Fences ★
Reparian Plantings ●●●●
Seeding Area
REMOVE
WOODY
DEBRIS
SPIRIT LAKE
Coldwater
GOAT MOUNTAIN
Harmony Falls Lodge
Boy Scout Camp

C. CLEARWATER DRAINAGE

Upper and lower Clearwater Creek including portions outside the blast area; excluding Bean Creek which flows into the Clearwater (30.64 square miles).

1. Geologic Conditions

a. Blast Effects - Primary blast effects in this system are most severe along western tributaries of the upper drainage in the Meta and Curtis Lake areas. Timber has been blown down in all previously unharvested areas of these sections. Thermal effects are present only in Sections 13 and 14 in the upper drainage basin. No evidence of airborne blast material was observed in this system.

b. Depositional Effects - Ashfall depths is this system range from 4 inches (1/4" ash - ML, 1" pumice, 3" sand - SMd) in the upper watershed to 10 inches (1" ash - ML, 6" pumice, 3" sand - SMd) near Paradise Falls. Mudflow and woody debris deposition are most significant in the lower drainage from the confluence of Muddy River to approximately 2 miles upstream. Within this zone numerous large hummocks of silt and woody debris exist in channel constrictions and meander bends.

2. Vegetation - The Clearwater Creek drainage, at the east and northeast limits of the blast and associated shock wave has been extensively cutover. Remaining timber was blown down and no surface vegetation survived. Even though numerous clearcuts existed, the remaining volume blown down is significant. There is much down material in the Clearwater channel. The valley bottom is flat and broad. Debris movement will be restricted.

Little vegetation was found resprouting through the ash and pumice layer. However, plants may push through the coarse material. Along the channel of Clearwater Creek, alder was noted to be resprouting. Based on observations, this riparian zone will probably be back to 50 percent of its original density by the fall of 1981.

3. Wildlife, Streams, and Lakes - This drainage is on the fringe of the blast. It did receive heavy ashfall, but the habitat should recover at a faster rate than Bean Creek or Smith Creek.

In Clearwater Creek, stream substrates are covered with 1-1/2 to 2 feet of ash sediment. Within the blast area, blowdown spans stream channels in areas of preeruption old growth Douglas fir.

4. Hydrologic - Clearwater Creek, along with the Green River, has the highest potential for hydrologic recovery. Average peak flows are about one-half of the more severely damaged basins.

Observed water quality was the best of the basins. Turbidities were only a fraction of those observed in other streams. Also, a large part of the upper basin is in a wide, low gradient, moist valley that can act as a "sink" for retaining some of the sediment and will recover relatively fast as riparian vegetation responds.

Lower Clearwater Creek is confined within a steep, narrow canyon below the confluence with Bean Creek. There are several low, apparently stable, woody debris jams. However, with predicted higher flows and the high debris potential from Bean Creek, these jams should be periodically evaluated. In Clearwater Creek, as well as Green River, water temperatures are expected to elevate. Fish have been observed in Clearwater Creek. It is important that shade-producing riparian vegetation be established.

5. Soils - Preeruption soils in the Clearwater Creek drainage have not been altered appreciably by volcanic activity, although considerable amounts of volcanic material have been deposited over them. Soils within the Clearwater Creek drainage between Muddy River and Bean Creek have been essentially unaffected.

Infiltration measurements taken at the Paradise Falls site were relatively high (1/2 inch in 35 sec.).

Well developed rill and gully erosion was observed on steeper slopes in old clearcuts only. Little surface and rill erosion was noted on the gentle slopes adjacent to the stream channel. The topography of this drainage basin should assist in reducing sediment delivery to the stream system.

The possibility exists for accelerated mass failures along the west side of the drainage. This area contains steep slopes, moderate to deep ash, and little or no transpiring vegetation.

The overland sediment delivery from this basin is estimated to be 358 acre-feet. See Appendix 5.

6. Channel and Gully - Channel and gully erosion are most severe on the west side of the upper drainage and through the mudflow deposits of the lower river. Calculated erosion rates varied from 3 acre-feet per mile in the upper watershed to 30 acre-feet per mile at the confluence with the Muddy River. The adjusted annual sediment yield from gully and channel erosion is 1,015 acre-feet per year from the Clearwater Creek system. No significant landslide activity was observed in this system, which possibly reflects the effects of the permeable pumice layer. See Table 4, Appendix 7.

One detention site was considered in the upper watershed, however the low storage to inflow ratio and relatively small sediment yield above the site precluded construction consideration.

7. Transportation - The drainage is accessible by roads 100.1 (at the headwaters) and N917. These roads are covered by medium heavy to heavy ash deposits. The roads are blocked by minor slides and fallen timber with a few breaches from erosion. Roads will be useable after cleanup and minor repairs. Access from the north is by roads 125.1 and 125.2. Access from the south by road 125.3 is blocked by a bridge being out over Muddy River.

8. Conclusions -

a. Fisheries and riparian vegetation will come back rapidly, so any disturbance of the stream should be done early.

b. Major sediment traps would not be cost effective.

c. The drainage contains a large volume of accessible timber on the ground.

d. Due to favorable geomorphology, the area has a good chance of recovery if treated properly, even with heavy ash deposits.

e. The basin shape and downed timber will help retard downstream movement of sediment and debris.

f. The transportation system is intact within the blast zone but has heavy ash deposits.

g. Disturbance of the surface crust during salvage will assist vegetation recovery.

h. Revegetation will improve habitat along the blast fringe.

i. Woody debris from lower Clearwater Creek will move downstream into the Muddy River unless it is removed. The impact downstream will be minor.

j. Road system to access the lower Clearwater Creek is severly damaged.

9. Recommendations - These recommendations are in addition to those in the General Section.

Short Term

a. Seeding as recommended in the seeding criteria. See Appendix 12.

b. Remove trees spanning the streams that are likely to be moved by floods this fall to avoid damaging the riparian area after recovery. Remove trees within 100 feet of each side of the stream bank or to the height of average flood flows. First priority for tree removal is upstream of the bridge in Section 3.

c. Leave downed timber through this winter. However, we see no insurmountable problems on the east side if downed timber is harvested this fall following the general salvage logging recommendations.

d. Salvage logs in lower Clearwater jam when accessible.

e. Use silt fences in existing clearcuts adjacent to riparian areas on slope less than 30 percent. Use silt fences with treated wood posts and ultraviolet light stabilized fabrics strong enough to be self supporting (no metal wire or metal posts). See specifications in Appendix 4.

f. Open roads on east side and north end of drainage only when ready to salvage timber since heavy maintenance will be required after the road is opened. Do not open roads on west side of drainage beyond the bridge in Section 3 on road N917 until after the 1980-81 winter.

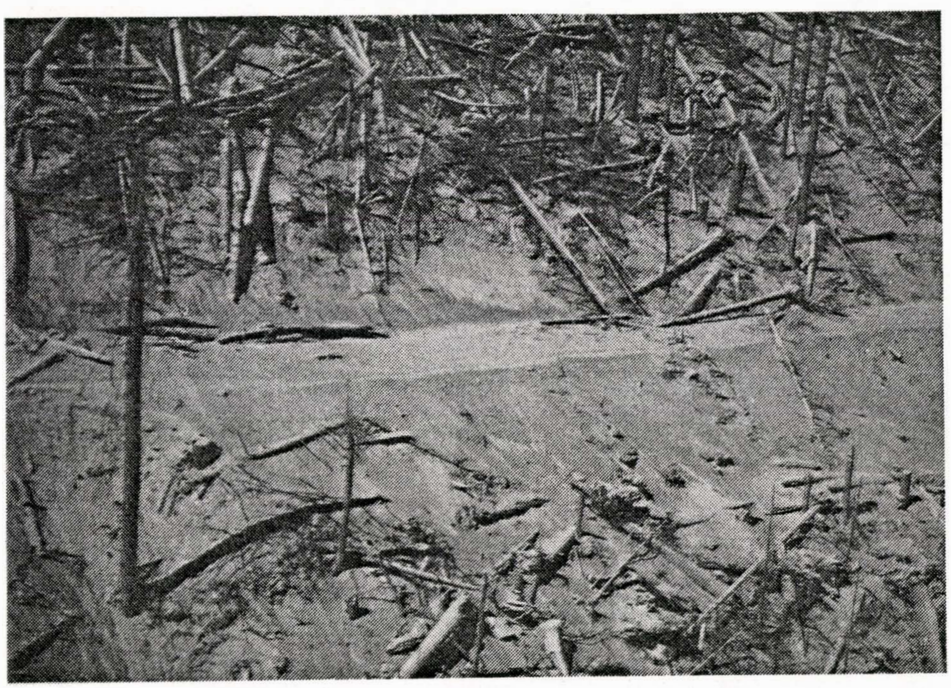
Long Term

a. Sprig and spike the riparian areas with vegetation if they do not come back spontaneously next spring.

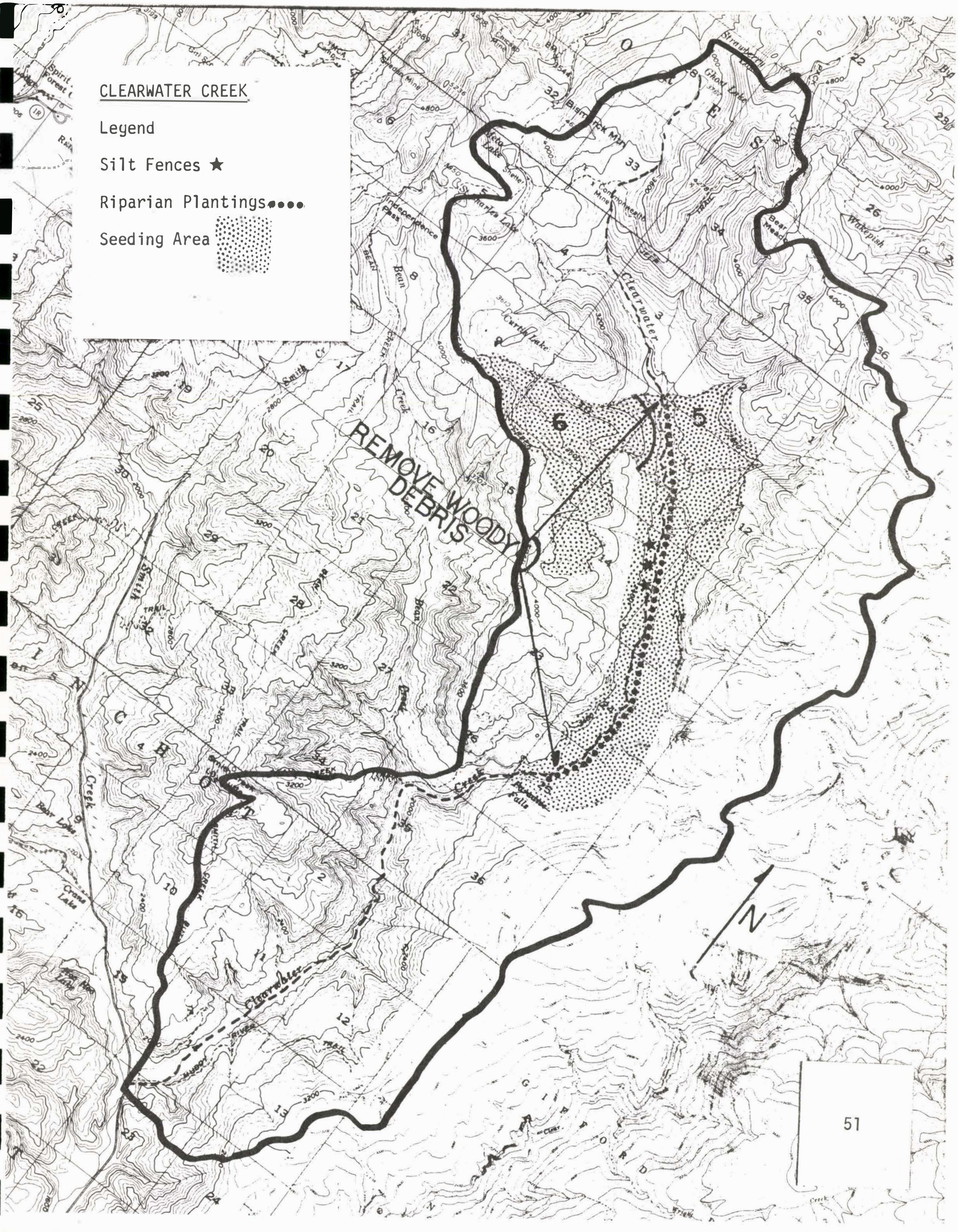
b. When salvaging, use silt fences to trap sediment next to riparian areas if enough wood debris and cull logs are not left.

CLEARWATER CREEK

Clearwater drainage from the south showing broad, U-shaped valley.



Transportation facilities have been severely impacted by deposition of volcanic materials in the Clearwater drainage.


CLEARWATER CREEK
Legend
Silt Fences ★
Riparian Plantings
Seeding Area
REMOVE WOODY DEBRIS
N
Clearwater
Curtis Lake
Independence Pass
Bismarck Mtn
Ghost Lake
Smith Cr
Bean Creek
Bear Lake
Crane Lake

D. BEAN - SMITH DRAINAGES

From lake origins to confluences with Clearwater Creek and Muddy River; these basins are grouped because they present similar conditions (31.70 square miles).

1. Geologic Condition

a. Blast Effects - Except for the North Fork Toutle River system, blast effects are more pronounced in Smith Creek and Bean Creek drainages than any of the other drainages. Blow down of vegetation within the drainages is almost total and along the western boundary, timber and topsoil were removed by the blast. Lakes in the drainages were subjected to what appears to be complete biologic destruction by the thermal blast and quenching of super heated ash and pumice deposits. There also appears to have been deposition of airborne debris along the western margin of the watershed.

b. Depositional Effects - These basins show the widest range of depositional effects of any drainages. The depositional axis for ashfall from the May 18 and July 22 events passes through the drainages and the deepest, most varied ash deposition was observed in these basins. Ashfall deposits range from 24 inches or greater along the western drainage margin to 12 inches (1/4" ash - ml, 3-3/4" pumice - SP, 8" black sand - SMd) in upper Bean Creek. This drainage system provides the best geologic cross-section of ashfall deposits that exists in the eruption area because it was downwind from the crater for 4 of the 6 major ashfall eruptions.

The upper tributaries of Smith Creek and Bean Creek received significant deposits of airborne debris. This material is most pronounced in the Independence Pass area and along F.S. Road #100 east of Spirit Lake.

Mudflow deposits blanketed the valley of lower Smith Creek with several feet of pyroclastic material and woody debris. Alluvial fan deposition at the mouth of Muddy River and Ape Canyon caused temporary damming of these flows and here the thicknesses of soil and woody debris probably exceeds 30 feet. Two natural constrictions in Bean Creek have similar deposits, but thicknesses probably do not exceed 20 feet. These deposits appear to be the result of rapid snowmelt and flooding which resulted from the deposition of superheated material on existing snowpack. In both cases, the material appears to have moved as a slurry incorporating massive amounts of woody debris. Peak flow scour marks are evident in many areas significantly above present deposits. In the case of Ape Canyon, the mudflows have removed the valley alluvium to bedrock. This is also true in the lower Bean Creek drainage.

Pyroclastic flow material exists on the mountain flanks above the south Smith Creek tributary. Flows of this type very likely moved down both the south Smith drainage and Ape Canyon and contributed to or initiated much of the mudflow activity.

2. Vegetation. These two drainages were devastated by the eruption and then buried by the ashfall. They had been extensively cut over. The remaining standing timber was either blown down, or killed on the stump. No live surface vegetation was observed and the depth of ash deposits will preclude rapid resprouting of residual herbaceous materials.

Severe erosion was observed within these drainages, which is exposing native soil. These areas will probably be revegetated by wind-born species next summer, primarily weedy types such as fire weed and thistle.

There are several large log jams within the channels in both drainages. Much of the down timber still remaining is on very steep slopes. It is probable that this material will move down slope as the result of precipitation and snow creep this winter and will end up in the stream channels. Salvaging this material this fall would prevent its entry into the channels where it would cause even greater bank and channel erosion. The material in Smith Creek and Bean Creek could move into the Muddy River and from there to Swift Reservior.

3. Wildlife, Streams and Lakes. Fish and Wildlife habitat within these drainages was severely damaged and completely altered by heavy ash deposition. The alteration has left a condition in these drainages where very few, if any, wildlife species that inhabited the drainages can survive.

Smith Creek and Bean Creek both have mud and debris flows covering the channel. These streams will be the last to recover, as stream channels and riparian ecosystems will have to be reestablished.

4. Hydrologic. Bean Creek and Smith Creek both drain very steep areas with considerable blast damage at the headwaters. Heavy ash and pumice deposit are present over much of the remaining area. There is down timber on the steep slopes (more so in the Bean than Smith) that will reduce surface erosion if it stays in place.

Very high peak flows are expected out of the Smith Creek drainage with Bean Creek about 20 percent lower.

Smith Creek drains high elevation areas from Mt St. Helens and will experience higher spring runoff than previously recorded because of lack of glaciers.

The upper Smith stream bottom is narrow and scoured, with little bank storage of water or opportunity for riparian vegetation reestablishment. However, lower Smith Creek below Ape Canyon is wider and sediment has collected in the bottom. There is more opportunity for reestablishing cover once the channel is stable. Channel stabilization will be slow because of high peak flows and instability of the deposited material.

5. Soils. Bean Creek and Smith Creek drainages have been severely impacted by deposition of volcanic material and vegetation removal.

Infiltration measurements taken in the upper Bean Creek site were approximately 1/4 inch in 1-1/2 minutes.

The potential to move and deliver large amounts of sediment exists due to the large amounts of deposited material, high drainage density, steep V-shaped canyons, and lack of vegetation. Extreme rill and gully incisement into preexisting soils has already been observed. Measured rill erosion in upper Bean Creek on July 10 (60 percent slope) ranged between 60 and 77 tons per acre. The potential also exists in these drainages to reduce long-term timber productivity because of increased erosion and mass wasting activity.

The overland sediment delivery estimate is as follows:

Upper Bean Creek	104 acre-feet
Lower Bean Creek	407 acre-feet
Smith Creek	2434 acre-feet

The derivation of these values is in Appendix 5.

6. Channel and Gully. Gully erosion is the most significant post-eruption effect in the Smith and Bean Creek drainage system. Dissection of the mudflow and ashfall deposits has been severe in the lower drainages. Calculated erosion rates range from 10 to 130 acre-feet per mile on Smith Creek and from 10 to 20 acre-feet per mile on Bean Creek for the period of May 18 to June 19, 1980. Calculated sediment yield for the system is 6,585 acre-feet per year. See Table 5 in Appendix 7.

Channel downcutting into mudflow deposits is also causing significant channel bank failure due to the grain size (SMd) and nonplastic nature of the material. Because of the thickness of ashfall deposits and percentage of steep slopes within this system and the low density of the material, it is anticipated that severe slope instability will occur as fall and winter rains and snow loading occur. This is particularly significant along the ridge separating Bean Creek and Smith Creek drainages where large areas are geologically unstable and past landslide activity has been frequent.

Some natural sediment trapping is expected behind the existing debris dams. Should winter runoff conditions be less than severe, significant sediment will be trapped in the lower Smith Creek drainage and behind the debris restrictions in the upper and middle Bean Creek basin. Should severe winter flood runoffs occur, much of the presently trapped soil and woody debris will be flushed downstream to lower log jam detentions or into Swift Reservoir on the Lewis River system.

Three detention sites were examined in the Smith Creek and Bean Creek drainages. Two are on upper Bean Creek and have limited storage capacity compared to annual inflow. The lower of these sites, located behind an existing log jam, will be somewhat effective even if no construction work is done. The jam is lodged in a narrow constriction in resistant bedrock. The upper site is in a small basin near the headwaters of Bean Creek and controls only a small percentage of the area. Because of these capacity-inflow ratios, limited drainage control, and construction difficulties, no further site consideration was made. A third detention site, which has a larger capacity, exists on lower Smith Creek. This site was discussed with Pacific Power and Light Company regarding beneficial effects of keeping sediment out of Swift Reservoir. Dead storage (available to sediment at no reduction of usable power storage) in the Swift Reservoir is in excess of 300,000 acre-feet. See Appendix 11. It was concluded that trapping volume was not significant in light of expected sediment yield. A further factor was the capacity inflow ratio of this site which will cause a rather low trap efficiency.

7. Transportation. The roads of upper Bean Creek in Section 5 (Road 100 and 100.2) and 8 (N92) are covered with heavy to very heavy ash deposits. There are numerous blockages from slides, down timber, and debris. The roads in the blast area of these drainages south of Sections 5 and 8 (T9NR 6E), are breached in many areas and blocked by mud and ash slides. The road prism is not visible in many areas. The heavy damage extends south in the Smith Creek drainage to Section 32 where Road N930 formerly intersected with N92. Road N930 between Smith Creek and Bear Creek is inaccessible due to destruction of N92 in Smith Creek and the Muddy River valley floor.

8. Bean Creek - Conclusions

a. The Bean Creek drainage was in direct line with the volcanic ash plume which formed as a result of the May 18 eruption. Consequently, this drainage received considerable fallout of volcanic ash and pumice (up to 12-1/2 inches).

b. Large amounts of soil material will be eroded. High amounts of sediment will be delivered to stream systems because of geologic instability, drainage topography, and high drainage density.

c. The upper and lower Bean Creek drainages are different. Stream gradients in upper Bean Creek are flatter and an opportunity for timber salvage exists. The topography in lower Bean Creek drainage is steeper with more blown down timber.

d. The Bean Creek drainage was an area of high geologic instability prior to the May 18 eruption. Mass movement activity may increase in the future as a result of almost total removal of all transpiring vegetation.

e. Rill and gully erosion in deep ash and pumice materials will most likely accelerate erosion of preeruption soils. This may result in a reduction of long-term forest productivity.

f. Vegetative recovery will be very slow due to the depth of deposited materials within this drainage.

g. On very steep slopes, in-place organic debris will move down slope and accumulate in drainage bottoms.

h. The Bean Creek drainage is located within the zone of rapid snow melt (2,000 to 3,500 feet). Rapid melt rates and snow creep will tend to cause organic debris movement.

i. The wildlife (fish, birds, mammals) population has essentially been destroyed.

j. The transportation system in lower Bean Creek has been almost completely destroyed. It will take a major reconstruction effort to restore it.

k. Two opportunities exist for sediment accumulation to occur naturally. The efficiency and capacity of these catchments could be enhanced by construction of barriers.

l. The log jam which exists at the lower end of Bean Creek is stable at the present time and will serve as a sediment trap this year. This jam may move in the future.

m. There is a high potential for high flows and associated woody debris movement out of the lower Bean Creek drainage.

n. Recovery of Bean Creek in terms of fisheries values will be slow regardless of any actions taken.

9. Recommendations - Bean Creek

Short Term

a. Remove timber this fall on the steep slopes below the debris jam should be considered if safe. (Secs. 26, 27, 34. T.9N., R.6E). Downed timber will most likely move into the channel off these steep slopes.

b. Retain log jams in lower Bean Creek as barriers to sediment movement, since they are stable.

c. Set up reference stations and permanent photo points for monitoring changes in log jams. If they should become critical, remedial measures can be taken.

d. See seeding proposal in Appendix 12.

Long Term

a. Leave mid-slope positions unroaded.

b. Maintain limited entry.

c. Spike the lower reaches of Bean Creek and alluvial fans above the debris jams with willow, alder, and black cottonwood.

d. In the upper Bean Creek basin, utilize fords for stream crossings in lieu of bridges or culverts.

e. Monitor seedling survival to evaluate seeding criteria.

10. <u>Conclusions - Smith Creek</u>

a. The Smith Creek drainage was in direct line with the volcanic ash plume which formed as a result of the May 18 eruption. Because of its proximity to the volcano, this drainage received the deepest ash accumulations within the devastated area (up to 24 inches).

b. The Smith Creek drainage has the highest probability of receiving volcanic ash deposition from possible future eruptions. Its headwaters are located on the flanks of the volcano.

c. This drainage was heavily cut over prior to eruptive activity.

d. Large amounts of soil material will be moved compared to other drainages. Higher amounts of sediment will be delivered to stream systems because of geologic instability, drainage topography, and high drainage density.

e. The eastern portion of the Smith Creek drainage was an area of high geologic instability prior to the May 18 eruption. Mass movement activity may increase in the future as a result of almost total removal of all transpiring vegetation.

f. Rill and gully erosion in deep ash and pumice materials will most likely accelerate erosion of preeruption soils. This may result in a reduction of long-term productivity.

g. Vegetative recovery will be very slow due to the depth of deposited materials within this drainage.

h. The Smith Creek drainage is located within the zone of rapid snow melt (2,000-3,500 feet). Rapid melt rates and snow creep will tend to cause organic debris movement.

i. Because of drainage topography, most in-place organic debris will move down slope and accumulate in channels.

j. The transportation system in Smith Creek is essentially nonexistent. It will take a major reconstruction effort to restore it.

k. High flow volumes with associated debris mobilization can be expected.

l. Recovery of Smith Creek in terms of fisheries values will be slow regardless of any actions taken.

11. Recommendations - Smith Creek

Short Term

a. This drainage should have last priority for any salvage operations.

b. Leave downed timber on the ground for as long as possible.

c. This drainage should have last priority for any salvage operations.

Long Term

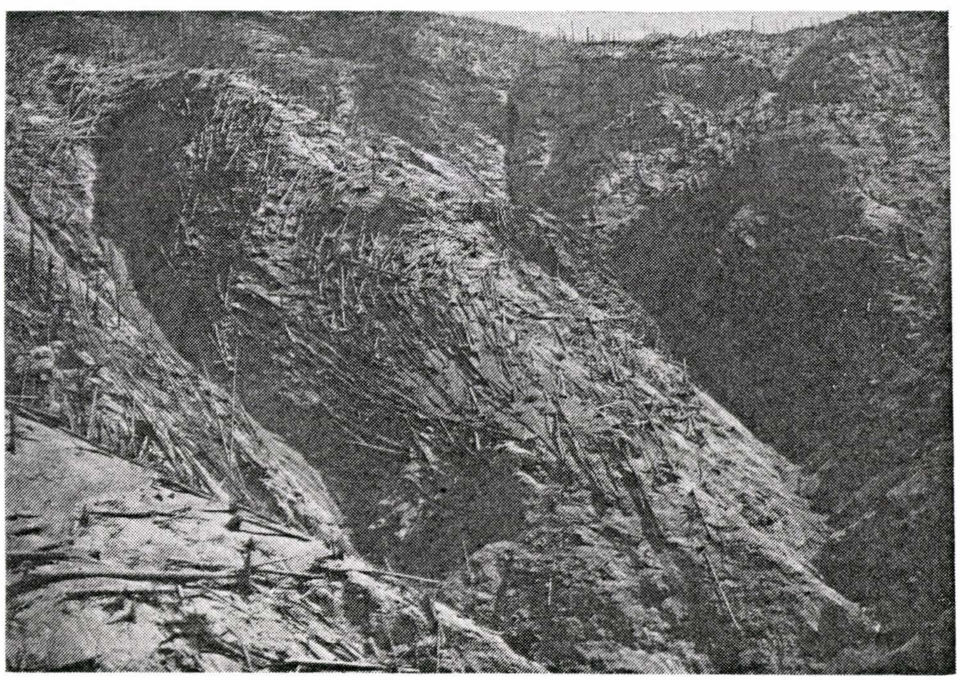
a. Spike the lower reaches of the drainage with willow, alder, and possibly black cottonwood.

b. Leave mid-slope positions unroaded, especially on the east side of the drainage.

c. Any new road construction should consider drainage dips and fords in lieu of culverts.

d. Leave log and debris jams in main channel to accumulate sediment.

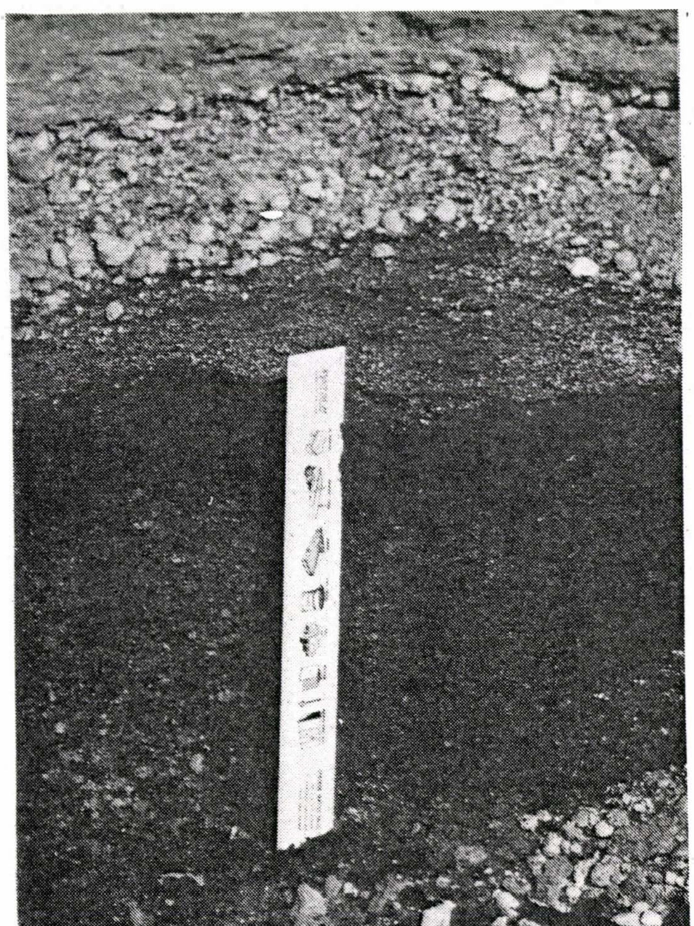
Downed timber on steep slopes provides an effective barrier to down-slope movement of ash and soil materials.



Down timber on steep slopes in lower Bean Creek.

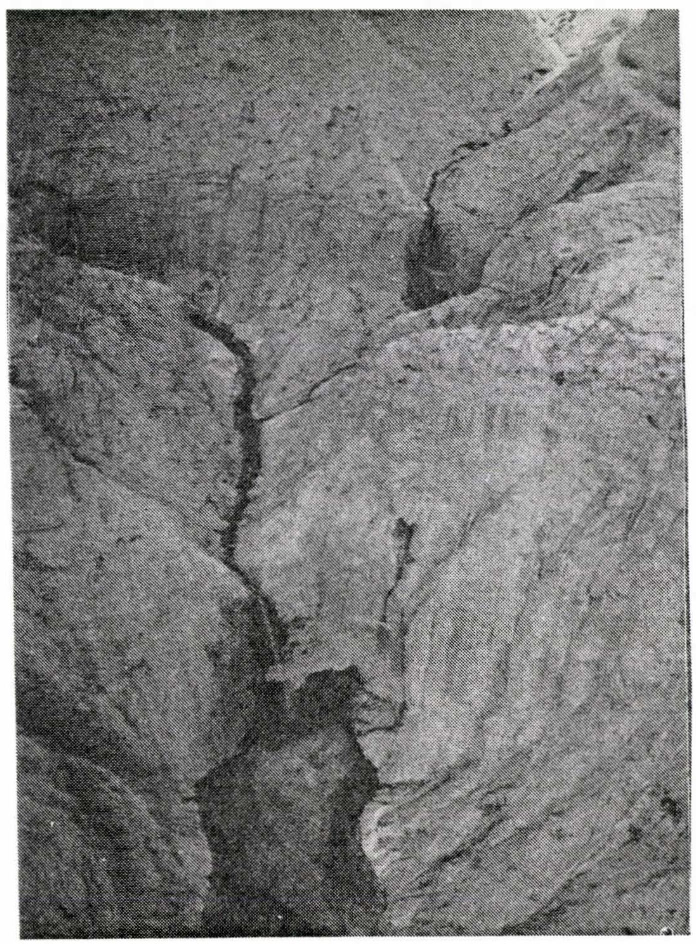
BEAN CREEK

Debris jam in lower Bean Creek.



Sequence of ash deposition. (12" ruler; sand, pumice, fine ash).

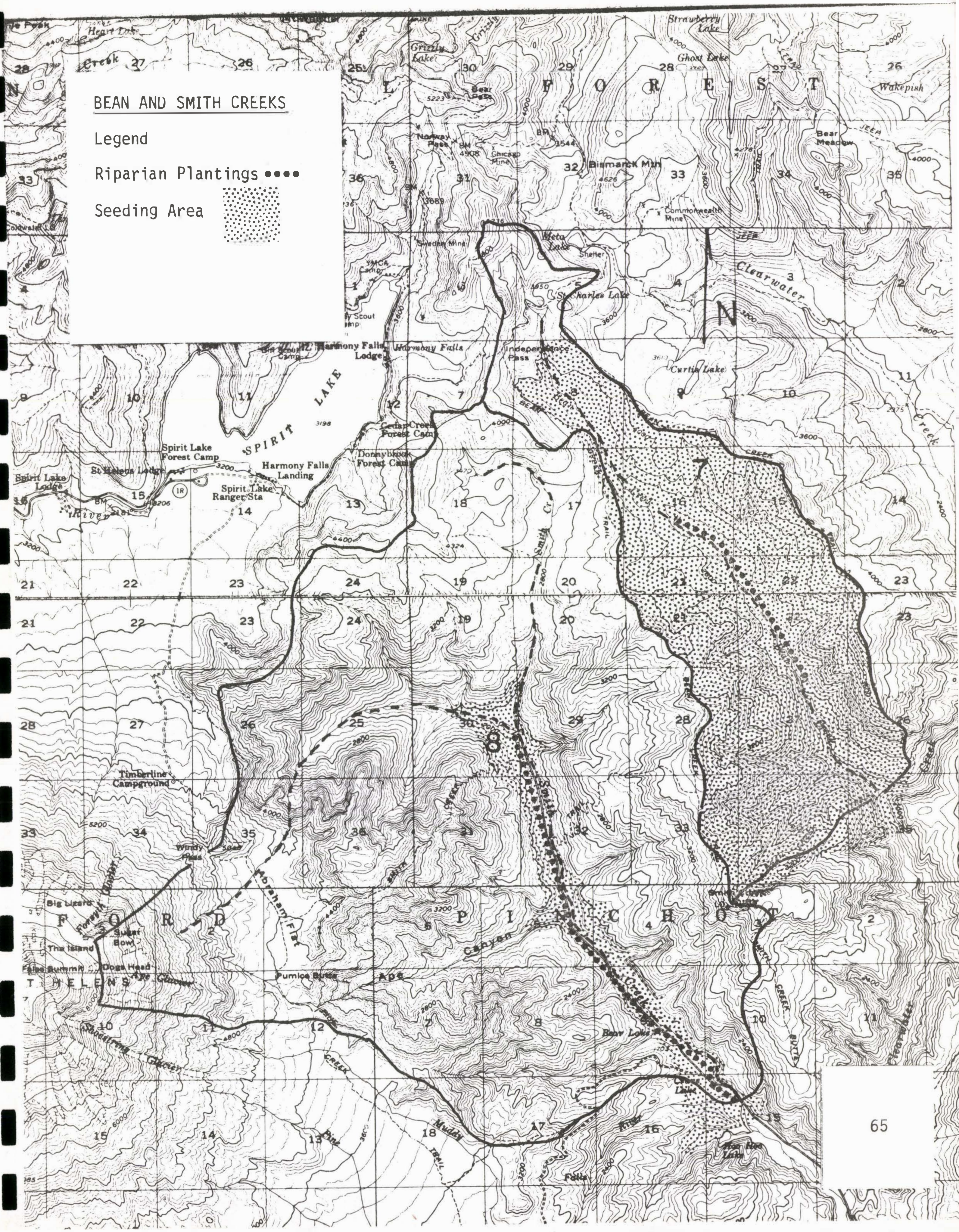
Denuded slopes and damage to transportation system in Smith Creek drainage.



A waterfall in the rugged terrain of Smith Creek.

Severe rill erosion occurring in cutover areas in Smith Creek.

Woody debris and mudflow material in Smith Creek.


BEAN AND SMITH CREEKS
Legend
Riparian Plantings ••••
Seeding Area
SPIRIT LAKE
Spirit Lake Forest Camp
St Helens Lodge
Spirit Lake Lodge
Harmony Falls Landing
Spirit Lake Ranger Sta
Harmony Falls Lodge
Harmony Falls
Cedar Creek Forest Camp
Donnybrook Forest Camp
Independence Pass
Meta Lake
St Charles Lake
Curtis Lake
Bismarck Mtn
Commonwealth Mine
Norway Pass
Chicago Mine
Bear Pass
Grizzly Lake
Strawberry Lake
Ghost Lake
Wakepish
Bear Meadow
Clearwater
Smith Cr
Timberline Campground
Windy Pass
Big Lizard
The Island
Sugar Bowl
Dogs Head
Pumice Butte
Abraham Flat
Ape Canyon
Muddy
Bean Lake
Hoo Hoo Lake
Falls
F O R E S T
P I N C H O T
N
7
8

E. MUDDY RIVER DRAINAGE

From the mountain top to the Lewis River; excluding Smith, Bean, Clearwater, and Clear Creeks. Peak flows on the Muddy River will include inputs from these basins (23.46 square miles).

1. Geologic Conditions

a. Blast Effects - The Muddy River was not exposed to significant blast effect except for portions of the upper drainage in the area of the Plains of Abraham.

b. Depositional Effects - Pyroclastic flow and ashfall deposits are limited to the upper watershed area. Major deposition features are the mud and debris flow features which exist in both the upper and lower Muddy River valleys. Material depths range from 10 to 40 feet in depth along the major drainage. A major alluvial fan deposit exists at the confluence of Smith Creek and the Muddy River. Log and soil debris hummocks exist in meander bends of the lower Muddy River and a major log and soil jam exists on the Muddy River at the Forest boundary.

2. Vegetation - The vegetation in this drainage in the upper quarter (Sections 12 and 18, T8N, R6E) was covered by mud flows. This area historically had mud flows and sparse vegetation, so no serious impact is believed to have occurred. The remainder of the Muddy River drainage was out of the blast area and not under the axis of the ash plume which followed the initial eruption.

Basic damage to the lower three-fourths of this drainage was scouring and bank cutting. The vegetation, with the exception of streamside willow and alder, was unaffected. The riparian vegetation will come back rapidly if root masses were left intact.

This stream runs through the Cedar Flats Research Natural Area. Just below this RNA is a very large log jam. The RNA could be affected with serious bank cutting and overflow if this jam is not removed. This could jeopardize the value of portions of the RNA.

With the exception of this jam there is little debris in this drainage. If it were to break loose and move downstream, it could seriously impact the streamside vegetation and channel of the Muddy River. This material will ultimately reach the Swift Reservoir.

3. Wildlife, Streams, and Lakes - The lower reaches of the Muddy River were outside the blast area. Because ash depth is light, fish and wildlife habitat will recover rapidly. The upper reaches were impacted

similarly to Smith Creek. The stream channel has been buried with the mud flows. This stream has historically been impacted by heavy sediment transport.

4. Hydrologic - The Muddy River from the confluence of Smith Creek has traditionally been unstable and meandering prior to the eruption. Water quality has never been relatively high even during summer months when the former glaciers of Mt. St. Helens were active and the stream was turbid with glacial "flour."

The total Muddy River drainage (including Smith, Bean, and Clearwater Creeks, but not Clear Creek) is the largest basin in the eruption area (86 sq. mi.). Total average annual runoff is in excess of 450,000 acre feet.

Peak flows are also expected to be very high, consequently there is great potential for channel changes, sediment transport, and woody debris movement in the lower reaches of the Muddy River mainstem.

The Muddy River (including the Clear Creek drainage) comprises 27 percent of the total drainage area into Swift Reservoir (which has held a maximum of almost 756,000 acre-feet), which is operated primarily for power by Pacific Power and Light Company.

Swift Reservoir, with a dead storage of over 309,000 acre-feet and two lower reservoirs, Yale and Lake Merwin, with dead storage of 178,000 and 159,000 acre-feet respectively, have a total dead storage of over 600,000 acre feet. See Appendix 11.

5. Soil - There has been little change in soil conditions in the Muddy River drainage since eruptive activity began. Most of the area has been covered with 1/2 to 1 inch of fine ash. Field observations indicate ash deposits are having little effect on vegetative growth. Surface and rill erosion rates have not increased significantly except for possibly on road surfaces, cuts, and fills.

6. Channel and Gully Erosion - Dissection of the mudflow deposits is the major erosional effect in this system. Calculated erosion rates range from 40 acre-feet per mile in the upper Muddy River to 50 acre-feet per mile in the lower drainage. Calculated sediment yield for the system is 9,700 acre-feet per year. See Table 6, Appendix 7.

One detention site was examined below the confluence at Clearwater Creek and the Muddy River. Construction is not recommended because of the low storage to sediment delivery ratio. Sediment capacity-inflow relationships are not favorable for continued consideration of a dam with a positive embankment volume to storage ratio. Also the value of lost active pool capacity in Swift Reservoir was not sufficient to produce a favorable benefit/cost ratio for construction.

7. Transportation - Road N92 along the Muddy Creek has been covered by mudflow and breached in many areas. The new stream channel bottom is nearly the same elevation as the old road surface due to channel filling. The old road surface will be underwater during most of the winter months. The bridges on Road 125 in Section 1 and across Pine Creek in Section 24 have been destroyed as has the bridge on N90 across the Lewis River in Section 26. Two or three bridges and several sections of road will have to be completely relocated and rebuilt to reestablish the transportation system in the drainage. The Upper Muddy Creek area is inaccessible via road N83 due to mud across the road.

8. Conclusions - The Muddy River historically transports high concentrations of suspended sediment and large volumes of bedload material. The river is characterized by a meandering and unstable channel.

a. Suspended sediment, bedload transport, and channel instability will increase, particularly during the first winter.

b. Debris torrents and mudflows scoured the floodplain destroying riparian vegetation.

c. Vegetation outside the floodplain was not adversely affected by the eruption.

d. A large debris jam has formed on the Lower Muddy River (Sec. 13) at the Forest boundary. This jam has a high damage potential. Much of the volume is salvageable.

e. Accelerated runoff and peak flows will occur, particularly below the confluence of Smith Creek with the Muddy River.

f. Two bridges and 6 miles of road were destroyed by debris torrents and mudflows.

9. Recommendations - These recommendations are in addition to those in the General Section.

Short Term

a. Remove the log jam in the Muddy River near the Forest boundary as soon as possible. If the jam can not be moved this fall, surveys should be conducted to determine where flood flows will go if the channel becomes blocked. This determination will guide whatever additional action is needed.

b. If bridges are required on a short-term basis, utilize temporary stream crossing structures that can be removed prior to winter flows.

c. Monitor the large log jam until removed.

Long Term

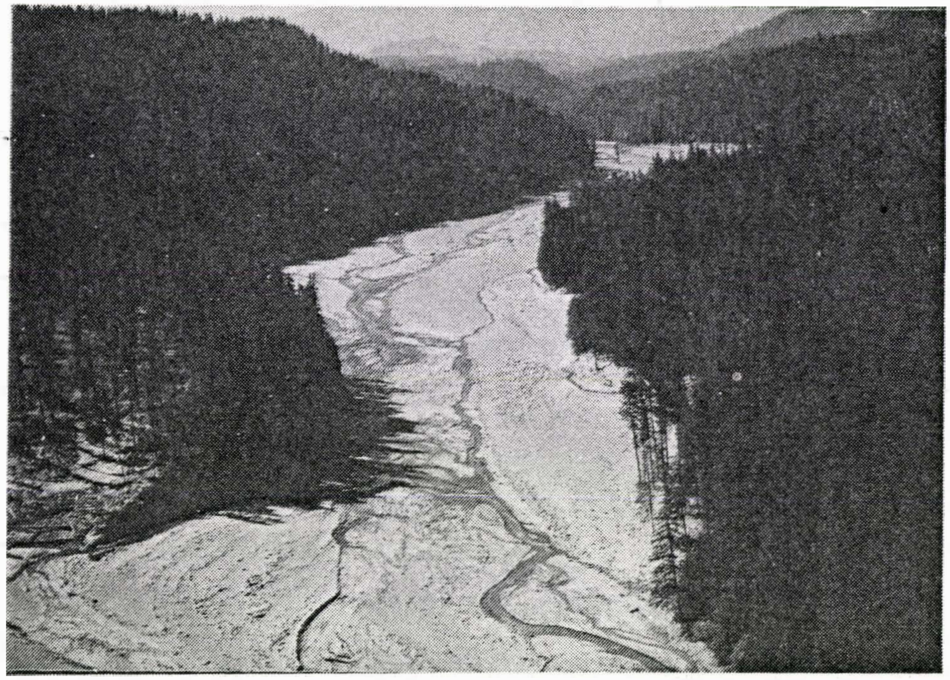
a. If riparian vegetation does not recover, plant willow, alder, and black cottonwood within the riparian zone in the Muddy River floodplain.

b. Remove log jams on Clear Creek and unnamed creek, 3/4 of a mile below the confluence of Clearwater Creek with the Muddy River.

c. If the road destroyed between the gauge station and the confluence of Smith Creek with the Muddy River is required, relocate the road outside the floodplain.

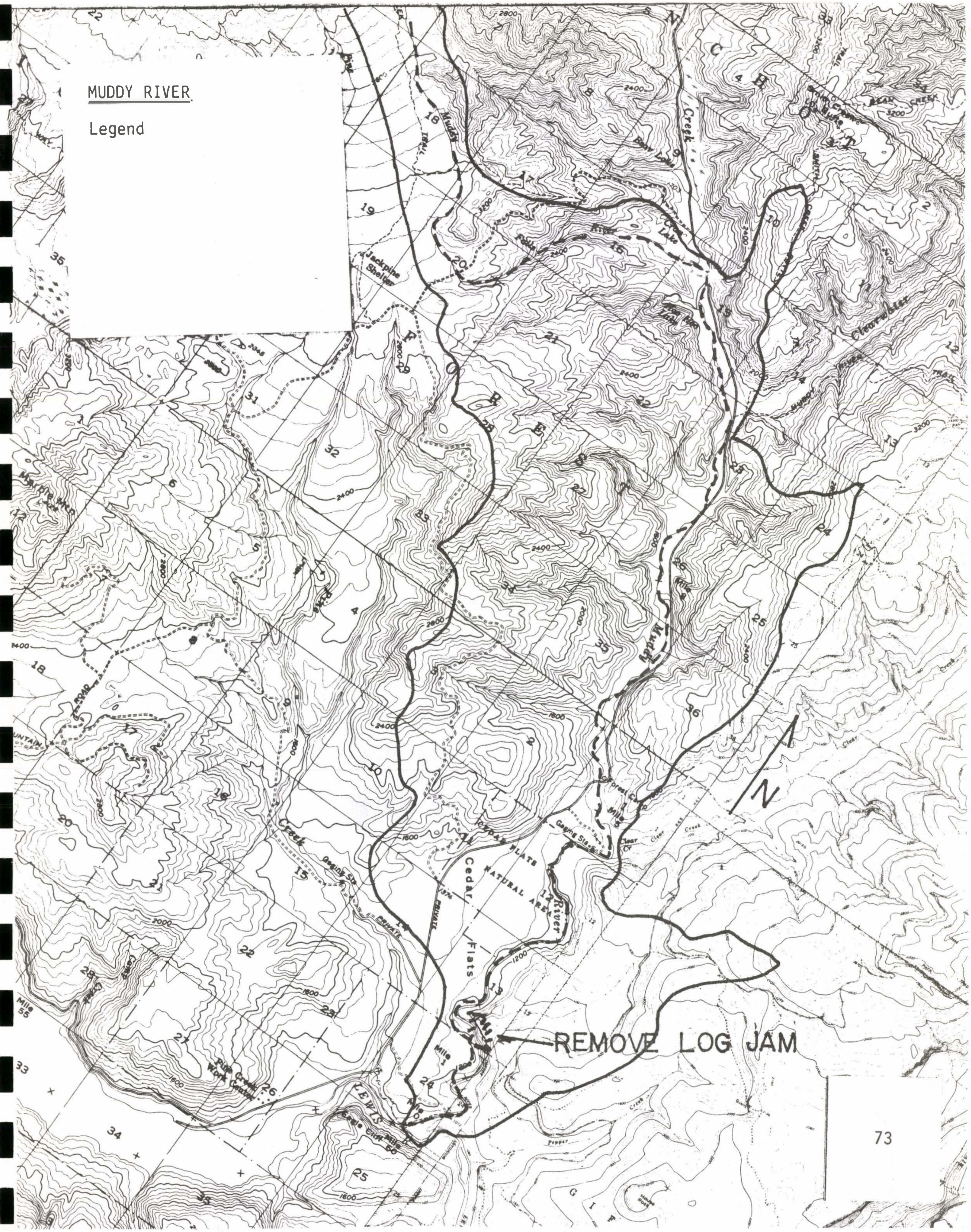
d. Do not harvest live timber immediately adjacent to the floodplain.

MUDDY RIVER



Lower Muddy River viewed from the north.

Debris jam at a constriction in lower Muddy River just above Swift Reservoir.


MUDDY RIVER
Legend
REMOVE LOG JAM
N
Jackpine Shelter
Muddy
Cedar Flats
CEDAR FLATS NATURAL AREA
Pine Creek Work Center
LEWIS
Clear Cr
Forest Camp

F. PINE - SWIFT - KALAMA DRAINAGES

From their origins to the Forest boundary; these basins are grouped because they present similar conditions (Pine 24.1 square mile, Swift 25.65 square mile, Kalama 8.34 square mile).

1. Geologic Condition -

a. Blast Effects - No significant blast effects were observed in this system.

b. Depositional Effects - Depositional effects are limited to ashfall and pyroclastic deposition on the upper Pine Creek drainage and mudflow deposits on the Pine Creek floodplain. Significant mudflow movement and deposition occurred in Pine Creek and left numerous perched deposits along steep bank sections. These deposits are now falling into the drainage.

2. Vegetation - The vegetation suffered only minor damage from the depositional effects. There is no large amount of debris or down timber in these drainages.

3. Hydrologic - These basins experienced some damage, primarily mud flows in the headwaters. Some turbidities were experienced immediately following eruption but no problems were observed during the field investigation.

Peak flows are not expected to be significantly affected as the preeruption vegetation has not been seriously altered.

Pine Creek and Swift Creek will be affected by the destruction of the glaciers. Glaciers were not a major contributor to past peak flows; however, as in other glacial streams, summer flows are expected to be lower.

4. Soils - There has been little change in the soil conditions in these drainages as a result of eruptive activity.

5. Channel and Gully - Erosion of the mudflow deposits is significant along Pine Creek. Calculated erosion rates range from 10 acre-feet per mile to 90 acre-feet per mile. Sediment yield for the system is calculated to be 7,575 acre-feet per year. See Table 7, Appendix 7.

6. Transportation - All three drainages are covered with light to medium-heavy ash deposits. Except for the east side of Pine Creek, most roads can be operational when the ash is removed.

Pine Creek is inaccessible from the southeast via Road 125 due to the bridge out across Pine Creek. Road N83 has been covered with mud in sections 20 and 29 near the headwaters of Pine Creek making the east side of the drainage inaccessible.

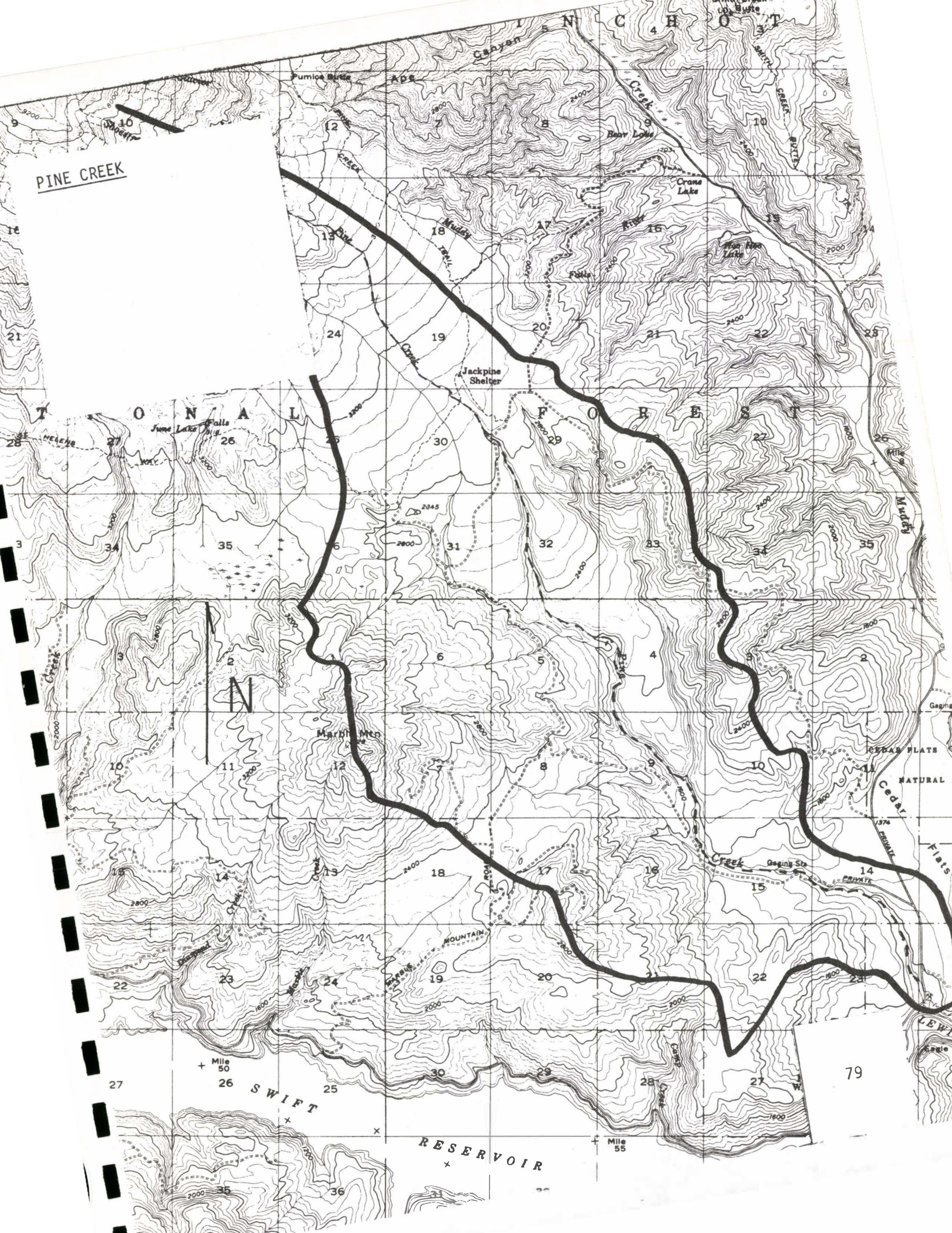
7. Conclusions and Recommendations - The recent volcanic activity has not appreciably changed conditions in Pine Creek, Swift Creek, and the Kalama River. Roads N83.1 and N727 were damaged along Pine Creek.

Sediment yield will probably be higher than normal from these streams.

We recommend no rehabilitation activities in these streams beyond reestablishment of damaged roads.

View of Mt. St. Helens from the south.

Headwaters of Muddy River and Pine Creek drainage. Muddy River disappears in the center-left of photograph.


PINE CREEK
PINCHOT
NATIONAL FOREST
Pumice Butte
Ape Canyon
Bear Lake
Crane Lake
Hoo Hoo Lake
Muddy River
Pine Creek
Smith Creek
Smith Creek Butte
Jackpine Shelter
June Lake
Big Falls
Marble Mtn
Marble Mountain Road
Cedar Flats Natural
Cedar Flats
Gaging Sta
Diamond Creek
Swift Reservoir
Mile 50
Mile 55
Lewis
Eagle

SWIFT CREEK AND KALAMA RIVER

G. SOUTH FORK TOUTLE RIVER DRAINAGE

Includes only that portion of the drainage basin on Forest land (6.47 square miles).

1. Geologic Condition

a. Blast Effects - Blast effects are limited in this system to areas of thermal impact on the northern fringe of the watershed.

b. Depositional Effects - Pyroclastic flows and ashfall deposits in the upper drainage and heavy mudflow deposits on the entire drainage are the major depositional effects within this system. Mudflow depths as recorded on tree trunks reached depths of approximately 50 feet in the vicinity of Herrington and Whitten Creeks. Depth of residual debris is estimated to be in excess of 20 feet near the mouth of Herrington Creek.

2. Vegetation Condition. The South Fork Toutle River took large amounts of volcanic debris, but little organic material. Flows affected many large trees high on the stream banks. These trees will probably die since half their circumference up as high as 20 to 30 feet has been debarked. This damage occurred on private land.

3. Wildlife, Streams, and Lakes. The streamside habitat was severely affected by heavy mudflows. The damage is similar to other channels inundated by mudflows. These streams will be the last to recover.

4. Hydrologic Condition. The South Fork Toutle River is expected to have very high peak flows. However, only a very small percentage of the drainage is within the Forest boundary.

The stream channel is filled with sediment. Most of this sediment does not appear to be pyroclastic flow but rather coarser, waterborne material. Consequently, turbidities may not be as high and the material may settle out more readily than the North Fork Toutle River.

Flow measurements on the South Fork Toutle River showed a much higher flow per unit area drained than the North Fork Toutle River indicating the lack of bank storage in the channel system. This may indicate peak flows will be dampened in those channel systems filled with massive mud flows (such as the Spirit Lake basin and North Fork Toutle channel).

5. Soil Condition. The channel has been impacted by a major mudflow which descended through Sheep Canyon. Other than vegetation removal in some areas and minor ash deposition, soil modification has been minimal.

Accelerated erosion will be confined to the area of mudflow deposition.

6. <u>Channel and Gully Situation.</u> Erosion of the mudflow deposits by channel and gully action has been extensive in the upper drainage. Calculated erosion rates range from 20 acre-feet per mile at Big Bull drainage to 1,260 acre-feet per mile near Disappointment Creek. The calculated annual system sediment yield is 12,500 acre-feet. See Table 8 Appendix 7.

7. <u>Transportation System.</u> There was no road in the South Toutle within the Forest boundary.

8. <u>Conclusions</u>

a. This drainage historically has had erosive soils particularly in and adjacent to the stream channels.

b. The channel incision will continue.

c. Erosion of stream banks will continue at an increased rate in the new deposits.

d. Deposition has impacted riparian zones but willows and alder sites will recover.

e. Timber that was debarked adjacent to the stream channel will die.

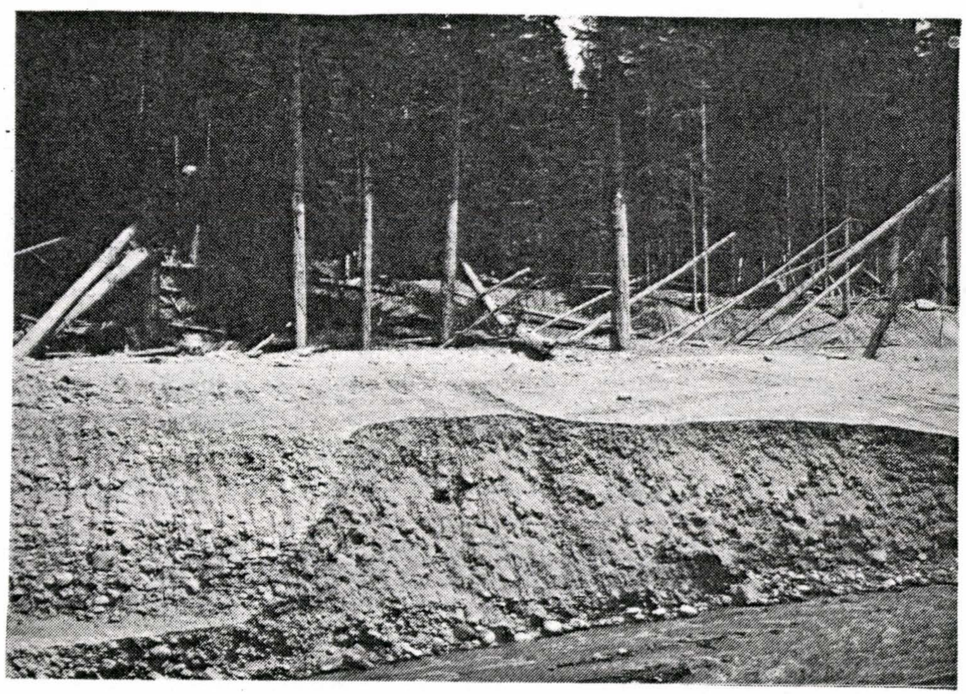
f. Fisheries of the mainstem were destroyed.

g. The flow that moved down the channel was not pyroclastic but rather saturated flow. This caused channel scouring but did reduce the amount of material that was deposited within the channel.

9. <u>Recommendations.</u> No action within the Forest boundary.

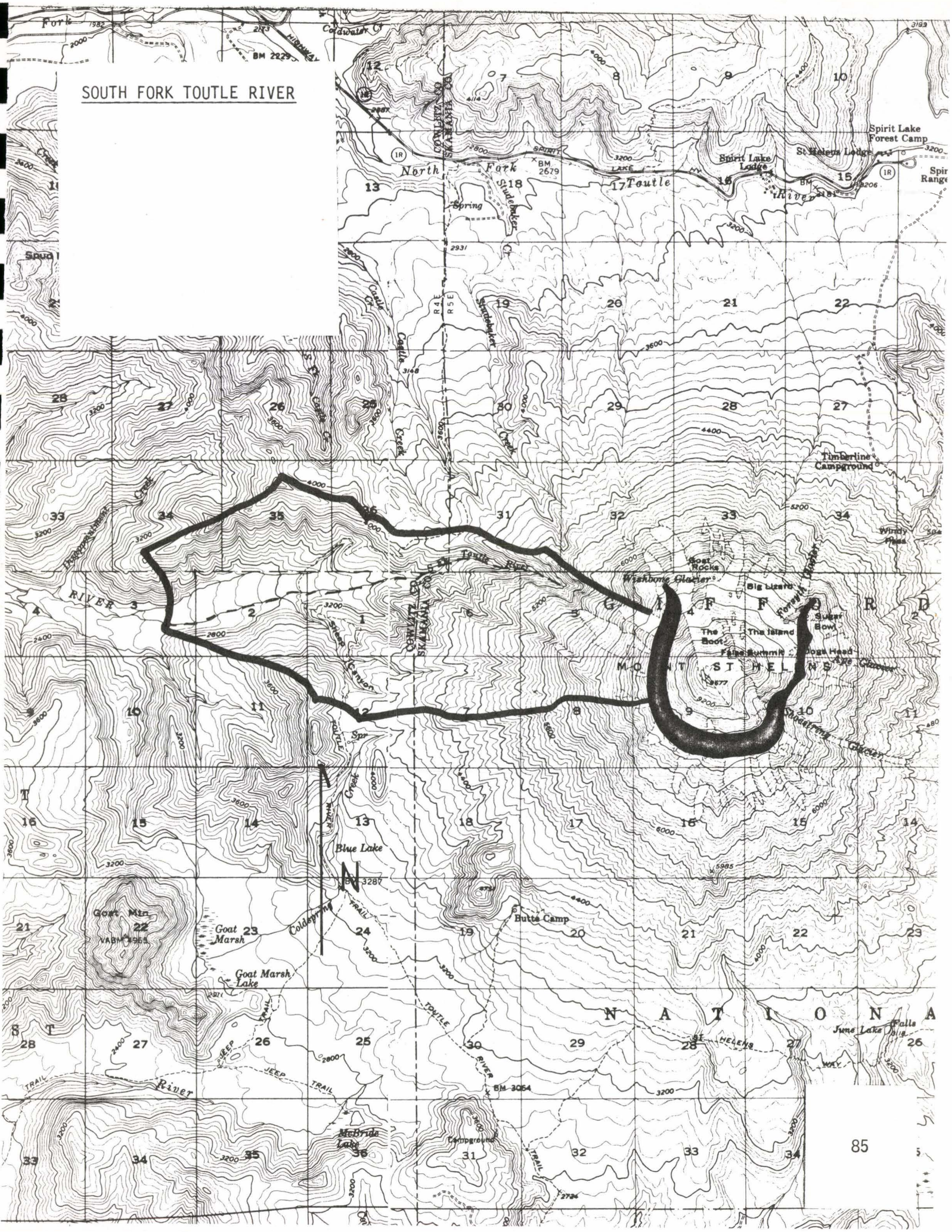
SOUTH FORK TOUTLE RIVER

Mudflow deposition in the South Fork Toutle drainage viewed from the west.



Mudflow deposits in the lower South Toutle drainage. Note high water marks on trees.

SOUTH FORK TOUTLE RIVER



SUMMARY

Post-Eruption Sediment Yields and Streamflow Conditions

Sediment yield from lands within the National Forest boundary is estimated to be in excess of 38,000 acre-feet (76 million tons) the first year. Over 85 percent of total sediment yields will be from channel and gully erosion. There is almost twice as much channel and gully erosion occurring outside the Forest boundary in the North and South Fork Toutle drainages.

Acrc-feet of sediment delivered to functioning channels is displayed in the Summary Table. Figures shown are primarily for the first year following the eruption. Amounts of delivered sediment will generally decrease over time as the amount of material available to be eroded decreases, channel and surface armoring occurs, and vegetative recovery progresses. Return to base level erosion rates will occur most rapidly in drainages where deposition of volcanic materials is least.

On-site movement of deposited volcanic materials and pre-existing soils will be high. Where effective groundcover is minimal, increased erosion rates may reduce the capability of a soil to support timber crops. Any form of revegetation may prove difficult.

Estimated post-eruption peak flows are expected to be from 2 to 20 times greater in small localized basins. Downstream impacts on inhabited areas will not be significant since the contribution from damaged areas to total peak flows originates on a small percentage of the total drainage basin. The main impact of localized peak flow increases will be increased sediment and woody debris transport capability.

Existing natural dams in the North Toutle drainage and small woody debris jams scattered throughout the devastated area will contribute significantly to the trapping of sediment if their structural integrity is sound and if they survive erosive processes. For example, in the Toutle basin, three dams (Castle Creek, Coldwater Creeks, and Spirit Lake) can trap over 35 percent (5,000 ac. ft.) of sediment the first year. Coldwater Creeks and Spirit Lake can continue to be effective traps for many years since maximum storage capacity for the two sites is over 600,000 acre-feet.

The only dam site in immediate danger of overtopping is Castle Creek where combined sediment and water inflow for a normal year is expected to be about 70 percent of total reservoir capacity. Should a high runoff year occur, the dam would be overtopped since estimated 100-year mean annual runoff into Castle Creek is almost 24,000 acre-feet.

The Spirit Lake site is not likely to be overtopped for many years even during a 100-year event, while the Coldwater site has about a two year period before overtopping unless a 100 year event (103,000 ac. ft.) occurs, which would overtop the dam in less than two years. These assessments do not include increase in reservoir life due to capacity gained by seepage (groundwater leakage) losses.

The short and long-term recommendations contained in this report are directed toward reduction of sediment delivery and protection of site productivity. It is believed these recommendations will promote rapid watershed recovery.

SEDIMENT AND STREAMFLOW SUMMARY

	Basin	Area (Sq. Mi.)	Annual Runoff (Ac.Ft.)	Peak Flow (c.s.m.)	Total First Year Sediment Yield (Ac.Ft.)			Existing Reservoir Capacity (Ac.Ft.)
					Channel & Gully	Surface	Total	
1.	North Toutle R.	20.34 1/	97,600	1,130	7,700	655	8,355	N/A
	a. Castle Cr.	3.10	14,900	1,130	300	612	912	22,000
	b. Coldwater Creeks	17.34	64,400	1,060	1,700	801	2,501	171,000
	c. Spirit Lake	16.13	77,400	1,130	465	1,129	1,594	440,000
		56.91	254,300					
2.	Green River	38.37	112,500	590	665	184	849	N/A
3.	Muddy	23.46 2/	112,600	1,060	2,930	no estimate	2,930	N/A
	a. Clearwater	30.64	96,300	660	1,015	358	1,373	"
	b. Bean	8.15	34,900	850	585	511	1,096	"
	c. Smith	23.55	101,000	1,060	6,000	2,434	8,434	"
		85.80	457,300					
4.	Pine/Swift	50.75	243,600	45	7,575	no estimate	7,575	"
5.	Kalama	8.34	44,300	60	no estimate made		-	"
6.	S. Toutle	6.47 3/	31,100	1,130	7,300	no estimate	7,300	"

1/ Exclusive of sub-basins shown; see drainage map in Appendix for detail of boundary.
2/ Exclusive of sub-basins shown and Clear Creek; see drainage map in Appendix for detail of boundary.
3/ See drainage map in Appendix for detail of boundary.

VI. INVESTIGATIVE PROCEDURES

A. General Procedure

The team spot-sampled selected locations after a thorough analysis of the pre and posteruption aerial photography (color and color infrared) and the interpretive work of the Lockheed specialists. Team members observed and recorded existing conditions, conducted scientific tests, collected samples, and photographed typical conditions on the ground. Ground locations were chosen to provide information representative of each drainage basin. See Appendix 13.

The entire area was also observed from low level helicopter flights. The flight paths and landings are shown on Map 3.

B. Functional Procedure

1. Hydrology - Estimates of peak flow, annual flow, and precipitation were made utilizing various models and existing data.

a. Annual precipitation and flow were determined from the Columbia-North Pacific Comprehensive Framework Study, Appendix V, April 1970.

b. Rainfall intensities were determined from U.S. Dept. of Agriculture and U.S. Dept of Commerce, September 1970 publication for the State of Washington. Daily rainfall amounts, May-June 1980, were from measured records by the National Weather Service.

c. Peak flows for various recurrence intervals were made utilizing the procedures contained in U.S. Dept. of Agriculture (Soil Conservation Service) publication SCS-TP-147, January 1968.

There were 12 continuous or instantaneous peak flow stations in operation in the general area. Various recurrence intervals of measured flows from these stations were computed utilizing the U.S. Geological Survey's computer program WATSTORE. These data were used to evaluate the predicted flows following eruption.

d. On-site streamflow estimates were made at five sites on two dates. It was not possible to make cross-section wading measurements of actual velocity and depth, so estimates were made of average depth, width, and velocity. Contained in the Hydrologic Data Summary in the Appendix are summaries of (1) rainfall intensities, (2) maximum peak flow (measured), (3) maximum peak flow (predicted), (4) current streamflow, (5) precipitation amounts, and (6) a list of hydrometeorological sites.

2. Overland Sediment Yield - An estimate of the contribution of sheet and rill erosion to total potential sediment production on a drainage basin was calculated using the Modified Soil Loss Equation (MSLE) and determining appropriate sediment delivery indices. The procedure used is outlined in detail by Warrington (in press) and is a modification of the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1965) for use on agricultural lands.

The MSLE predicts soil movement from sheet and rill erosion on an average annual basis; however, it may tend to overestimate quantities of soil moved over a long period of time (Megahan, 1974). Factors affecting the rate of erosion at any given point in time include amount of material available to be eroded, surface armoring, and vegetative recovery. Upon disturbance, a given soil may have a very high erosion rate which decreases rapidly over time. The MSLE projects erosion at a constant rate over time. The MSLE is also generally used on site specific projects rather than very large areas. Data needed for the equation can be easily gathered and is more reliable in small project areas.

Predicting sediment delivery coefficients is also very site specific. Factors that influence sediment delivery such as water available for overland flow, surface roughness, percent ground cover, slope shape, and delivery distance are very difficult to determine on a whole drainage basis.

The MSLE and associated sediment delivery coefficient calculations should prove useful in the Mt. St. Helens devastated area. These calculations can point out in relative terms, where sheet and rill erosion will contribute most to sediment loading and predicted impacts of future management activities.

A detailed description of the MSLE and methods of determining each of the factors is included in Appendix 6.

In order to operate the MSLE, some knowledge of textural and infiltration properties of the soil materials must be known. Textural properties were determined by the U.S. Forest Service, Pacific Northwest Region, Engineering Soils and Materials Testing Laboratory, Portland, Oregon. These data are included in Appendix 8.

Infiltration properties were determined in the field using a modification of the double-ring infiltrometer standard test method.

In order to determine the amount of rill erosion that had occurred prior to the time of field investigation, the Alutin rill erosion transect method was employed (Soil Conservation Service). This method is described in Appendix 6.

Each drainage basin was subdivided into major slope and cover conditions. The MSLE was then applied to each one of these major subunits to determine the approximate amount of gross erosion occurring. An estimate of a sediment delivery coefficient was obtained using the method described by Warrington (in press) for each drainage as a whole. Gross erosion figures were multiplied by sediment delivery coefficients to determine amounts of sediment reaching stream systems.

3. Gully and Channel Erosion - To determine the initial amount of sediment yield from gully and channel bank erosion, the following procedure was used:

a. Transects of gully and channel erosion across major drainages were measured to calculate cross sectional areas eroded during the period May 18, 1980, (date of major eruption) and June 19, 1980, (date of aerial photography flight MSH-C80 1:24,000). Selected field verifications were made to proof the calculations.

b. Drainage areas above major drainages, natural detention sites, and potential detention sites were determined by planimeter on 1 inch = 1 mile scale maps for detention and 1 inch = 2,000 feet scale maps for structure sites.

c. Erosion rates determined from transect measurements for the period May 18 to June 19 were adjusted to annual rates by the ratio of precipitation during the period to average annual precipitation for that area. Runoff relationships were not used because of rapid snow pack and glacier melt influences.

d. Acre-feet of sediment delivered was determined by adjusting the annual erosion value by the percent sediment delivered (from SCS National Engineering Handbook, Section 3, Chapter 6).

4. Reservoir Capacities - Reservoir capacities were determined by the following procedure:

a. Natural dam elevations were obtained from USGS 1:24,000 topographic supplements showing posteruption topography.

b. Posteruption topography was transferred to existing 1:24,000 topographic maps of Castle Creek, Coldwater Creek, and Spirit Lake drainages.

c. Maximum waterlines were drawn and reservoir cross sections constructed.

d. Reservoir capacities were calculated from cross sectional areas.

e. Surface areas were planimetered.

5. Foundation Geology - Foundation geology of natural reservoir sites were evaluated by the following procedure:

a. Preeruption channel conditions and materials were researched in existing publications and maps.

b. Posteruption material variation was observed, sampled, and tested from channel banks, hummock and scarp faces, and general surface exposures.

c. Permeability was evaluated from material tests, field infiltration rates, and observation of existing water level relationships in craters, channels, and impoundments.

d. Material tests were made of representative samples obtained from channel sampling a steep exposure of pyroclastic flow material to assess mass composition. Field density of the pyroclastic flow material was determined at one location using a 2 inch diameter tube sampler.

e. Knowledge of geologic processes was applied to develop ranges of possible conditions.

6. Evaluation of Landslide Conditions - To assess the stability conditions of ash covered slopes, an air photo interpretation was made of preeruption landslide terrain. High altitude photography 1:70,000 and 1:24,000 color flights were utilized to:

a. outline areas of previous geologic instability,

b. assess relationships of landslides to existing rock types, topographic conditions, and transportation facilities, and

c. relate areas of previous instability to areas of known eruptive deposits of ash, pumice, and pyroclastics.

7. Physical Properties - Field samples were collected and measurements made at a number of locations (Map No. 2) to determine depth and physical properties of newly deposited volcanic materials (ash, pumice, sand, pyroclastic flow materials, etc.).

Field disturbed (bag) soil samples of 10 to 15 pounds each were collected for tests of physical properties. Undisturbed samples were used for field moisture and density measurements. The undisturbed samples were collected by pushing a 2-inch diameter by 5-inch long (approximate) thin-walled soil sampler into the material. For ash depths less than 4 inches, the sampler was pushed through the layer and trimmed several times until completely filled with the layer being sampled. Moisture content and density calculations were completed in the laboratory.

All samples were classified according to the American Association of State Highway and Transportation Officials (AASHTO) and Unified Soil Classification Systems. Several groups of tests were run on the samples:

a. Atterberg limits, grain size analysis, specific gravity, and sand equivalency tests were run to aid in classification and to document basic physical properties.

b. Resistivity and pH tests were performed to provide corrosion information for metal structures.

c. Field and laboratory moisture density and permeability testing was performed to evaluate and predict field performance, including reaction to construction, maintenance, and salvage activities.

d. Laboratory strength testing and a field density test were performed to aid in predicting field performance and stability calculations for newly created dams.

e. Laboratory shrinkage tests were performed to determine if the shrinkage cracks found in the field were a result of the eruption/deposition mechanism or due to physical properties of the material.

f. Field infiltration tests were performed using a modification of the double ring infiltrometer (ASTM Test Standard D3385) in the lower Clearwater, upper Bean Creek, and upper Green River. These tests, performed with approximately 4 inches of head, measured expected field infiltration rates. These values were used to check permeabilities measured in the laboratory and values used in developing soil erosion rates with the Modified Soil Loss Equation.

A series of visual infiltration tests using spray bottles were run to determine wetability of the surface crust. Tests were performed using distilled water and distilled water with agricultural wetting agent additives.

8. Vegetation - Vegetation emerging through ash deposits and growing in rills and gullies was identified and in most cases photographed, but no statistical estimates of ground cover were made. Excavations were made to check root growth where no above ground evidence of plant life was found. Ash depths were measured each place vegetation was studied.

Site evaluations were made to assess the relative effects of salvage logging on recovering vegetation and erosion potential.

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Hinkle, Dick, Lockheed Engineering Services

Johnson, Tom, Lockheed Engineering Services

Landolt, Randy, Pacific Power and Light Company

McCoy, Gene, Chief, Foundations and Materials, Corps of Engineers

Mathews, Guy, Materials Testing Laboratory, Federal Highways Administration

Powell, Bill, Materials Engineer, Gifford Pinchot NF

Prill, Jim, Lockheed Engineering Services

Rea, Paul, Hydrologist, Gifford Pinchot NF

Reilly, Tom, Geologist, Gifford Pinchot NF

Ruediger, Bill, Wildlife Biologist, Gifford Pinchot NF

Sarna-Wojciki, Andrei, M., USGS, Menlo Park, California

Schroeder, W. L., Director, Engineering Experiment Station, Oregon State University

Schuster, Bob, USGS

Sedell, Jim, Pacific Northwest Experiment Station

Steurgill, Jay, Geologist, Corps of Engineers

Swanson, Fred, Pacific Northwest Experiment Station

Townsend, Lyn, Soil Conservation Service

Wade, John, Soil Scientist, Gifford Pinchot NF

Waite, Dick, USGS, Menlo Park, California

Biography - James W. Edgren

Education

BS 1957 Forestry, Iowa state University
MS 1959 Plant Pathology, Iowa State University

Experience

1959. Instructor, Botany department, Iowa State University. Taught beginning Botany to freshmen.

1959-1965. Researcher, plant disease project, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Planned and conducted research studies on diseases of forest trees, specializing in dwarf mistletoe, needle blights, and heart rots.

1965-1977. Researcher, nursery practices, and reforestation project, Pacific Northwest Forest and Range Experiment Station, Portland and Corvallis, Oregon. Planned and conducted research studies on reforestation subjects and published results as research papers and notes, or in proceedings of Western Nursery Managers Conventions. A partial list includes:

1. Bed density and size of ponderosa pine seedlings at the Bend Nursery. Tenth Biennial Western Forest Nursery Council Meeting Proceedings, 1966 (pp. 21-29).

2. Dwarf mistletoe effects on ponderosa pine growth and trunk form. (With T. W. Childs). 1967, For. Sci. 13(2):167-174.

3. Douglas-fir nursery stock survival by age class. Western Forest Nursery Council Proceeding, 1968 (pp. 52-56b).

4. Potential damage to forest tree seed during processing, protective treatment, and dissemination. USDA, Forest Service, PNW Exp. Sta., Res. Note PNW-89, 1968, 8p.

5. Growth of frost damaged Douglas-fir seedlings. USDA, FS, PNW Exp. Sta. Res. Note PNW-121, 1970, 8 p.

6. Sizing seed reduces variability in sowing ponderosa pine. (With Charles A. Bigelow.) Proceedings of Joint Meeting, Western Forest Nursery Council and Intermountain Forest Nurserymens Association, 1972 (pp. 12-18).

7. Artificial regeneration. (With William I. Stein). IN: Environmental effects of frost residues management in the Pacific Northwest. USDA, FS, PNW Exp. Sta., Gen. Tech. Rpt. PNW-24, 1974, (p. M-1 to M-32).

8. Field survival and growth of Douglas-fir by age and size of nursery stock. USDA, FS, PNW Exp. Sta., Res. Pap. PNW-217, 1977, 6p.

9. Seedbed density, diameter limit culling, and 2+0 Douglas-fir seedling production. Proceedings of Joint Meeting, Western Forest Nursery Council and Intermountain Nurserymens Association, 1977, p. 87-95.

1977-present. Reforestation specialist, Pacific Northwest Region, Portland, Oregon. Serves as staff specialist on subjects relating to long range nursery program planning; planting stock standards and quality; the physiology of nursery stock handling; plantation survival and growth; plantation stocking and growth standards; inspections and activity reviews; functional assistance to field units; and training of District and Forest silviculturists and reforestation workers. Publications include:

1. Immersion determination of seedling root-top ratio and its correlation with a drought resistance index. TPN 30(1):8-10, 1979 (with Jaya G. Iyer).

2. Range Management + Soils Management + Timber Management = Forest Management, or Trees and Grass. IN: Coordinated Resource Management Planning in the Pacific Northwest on Private and Public Lands. Washington State University, 1979 (p. 84-91).

3. Field performance of undercut Coastal and Rocky Mountain Douglas-fir 2+0 seedings. TPN (In Press.).

4. The Reforestation System--A Team Effort. IN: Proceedings, North American Forest Tree Nursery Soils Workshop, 1980. (In Press.).

BIOGRAPHY - Robert W. Hamner

Education

Bachelor of Science - Forest Management - Southern Illinois University - 1962

Master of Science - Range Management - University of Wyoming - 1964

Experience

Have worked in many of the major western Ecosystems in range revegetation and rehabilitation.

1. Pinyon-Juniper control and forage reseeding in eastern Nevada - 1964 - 1965.

2. Idaho Batholith stringer meadow rehabilitation in northern Idaho 1965 - 1970.

3. Mountain Grassland reseeding - northern Idaho, western Montana - 1968 - 1975.

4. Invading shrub (Big Sagebrush) control - southwestern Montana - 1970 - 1975.

5. Invading tree and shrub control - eastern Montana and western South Dakota - 1975 - 1978.

6. Shrub control and range rehabilitation - western North Dakota - 1979 - 1980.

Professional and Honorary Society Affiliation

1. Life member - Society for Range Management

2. Xi Sigma Xi

3. Alpha Zeta

Publications and Presentations

1. Revegetation of Sharlow Drill Site Locations in southeastern Montana - Society for Range Management Annual Meeting, San Antonio, Texas - February 1978. Co-Author.

2. Revegetation Progress Report - Wyoming Agricultural Experiment Station - 1964.

3. Revegetation Progress Report - Wyoming Agricultural Experiment Station - 1963.

BIOGRAPHY - Gordon H. Haugen

Education:

B.S. - Fish and Wildlife Management, Montana State College (1962)
Post Graduate Fish and Wildlife, University of Alberta (1966)
M.S. - Fish and Wildlife Management, Montana State University (1968)

Experience:

A. Regional Fishery Biologist, 1977 - present. Responsible for the development of Region 6's anadromous and resident salmonid fishery program, which includes habitat assessment, protection, and enhancement.

B. Zone Fishery Biologist, 1975-77 (Beaverhead, Custer, Gallatin, Deerlodge, Helena, and Lewis and Clark). Responsible for fishery management program on the six eastside Forests. Team Leader, Eastside Rehab Team, coordinated 216 rehab. projects, and developed riparian habitat studies and management direction.

C. Zone Fishery Biologist, 1970-75 (Lolo, Deerlodge, and Bitterroot NF). Responsible for fishery habitat management programs. Coordinated the Rock Creek Water Quality and Fish Habitat Study.

D. Department of Lands and Forests, Lethbridge, Alberta, Canada, 1967-1970. Regional fish and wildlife supervisor, South Saskatchewan drainage region, Alberta Department of Lands and Forests, Alberta, Canada. Responsible for fish and wildlife resource management in the South Saskatchewan drainage.

E. Department of Lands and Forests, Edmonton, Alberta, 1963-1967. Regional Fisheries Biologist, North Saskatchewan, Peace River drainage. Responsible for sport and commercial fishery management for the Department of Lands and Forests. Developed and coordinated the Tri Creek Watershed Investigation.

Professional Involvement

- President Western Division American Fisheries Society, 1980
- President of the Great Plain Fishery Association, 1964-65.
- Secretary--Treasurer, Canadian Society of Fishery and Wildlife Biologists, 1966-67.
- President of the Montana Chapter of the American Fisheries Society, 1976.
- Alberta Conservation Award (AFEA), 1968.
- American Institute of Fishery Research Biologist.
- Certified Fishery Scientist, AFS #513

Technical Papers Given Since 1970

- 1971 - Montana Chapter (AFS) - "Watershed Management on the Lolo N.F."
- 1973 - Western Division (AFS) - "Rock Creek Fishery Habitat and Water Quality Study"
- 1975 - Montana Chapter (AFS) - "Bedload Sampling, A Method for Field Application"
- 1977 - APO - 208 - "A Review of Grazing Impacts in S.W. Montana"
- 1978 - Society of Range Management (N.W. Section) - "Managing Riparian Ecosystems for Fish and Wildlife in Eastern Oregon and Eastern Washington"
- 1979 - Pacific N.W. River Basin Commission - "Anadromous Fish and Multi-Purpose Water Use" - Spokane, WA

BIOGRAPHY - Steven W. Howes

B.S. Range Management, 1972, Washington State University
M.S. Range Management, 1977, Washington State University

March 1980 to Present - Serves as Soil Scientist in the Division of Watershed Management, Pacific Northwest Region, U.S. Forest Service, Portland, Oregon. Areas of specialization include all aspects of soil management related to long term forest productivity including forest fertilization and utilization of nitrogen fixing species. Has developed guidelines for monitoring impacts of forest management activities on soil resources and for conducting forest soil surveys. Serves as liason between Pacific Northwest Region and Watershed Systems Development Group in Ft. Collins, Colorado. Graduate of Northern Region Program of Continuing Education in Forest Ecology and Silviculture.

1976 to March 1980 - Served as Soil Scientist on Mt. Hood National Forest, Portland, Oregon. Duties included completion of a Soil Resource Inventory (SRI) for the entire Mt. Hood National Forest. A Soil Resource Inventory integrates soil, geologic, landform, and vegetation data, and interprets those data for use in land management planning. Basic soil information contained in an SRI includes the description and classification of basic soil-land form units and the interpretation of chemical and physical laboratory data.

Made technical soil management input for timber sale projects on both the Mt. Hood National Forest and the Wallowa-Whitman National Forest. Inputs included assisting in determining suitable logging systems, and predicting soil response to various management activities such as harvesting, site preparation, and slash disposal.

Assisted in monitoring yearly soil moisture and temperature fluctuations as well as soil compaction on on-going timber sales.

1974-1976 - Served as Forest Soils Specialist for the Washington State Department of Natural Resources, Olympia, Washington. Assignment was to assist in evaluating all privately owned timberland in the State on a potential productivity basis. This was done by employing a standard detailed soil survey and correlating timber productivity with soil types and phases. Soils were mapped and classified according to National Cooperative Soil Survey standards. Interpretations of data were made to aid Forest land managers.

Prior to 1976, as a graduate research assistant, was employed on a research project designed to determine soil-site relationships of ponderosa pine in the inland northwest.

BIOGRAPHY - Peter V. Patterson

B.S. Engineering Geology - Oregon State University
M.S. Structural Geology - University of Oregon

Registered Geologist
Certified Engineering Geologist

Geophysicist - Texas Company, 1960-1961. Seismic reflection exploration and subsurface mapping for petroleum exploration.

Engineering Geologist - USDA, Soil Conservation Service, 1961-1970. Design and construction at PL-566 dams - Oregon. Responsible for foundation and materials investigation, sediment yield analysis, and construction operations geology.

Engineering Geologist - USDA, Forest Service, Mt. Hood National Forest, 1971-1976. Geotechnical support to Forest engineering operations. Responsible for rock resource development and geologic analysis of slope stability problems and facilities foundations. Leader, Geotechnical Engineering Section, 1975-1976.

Civil Engineer - U.S. Army Corps of Engineers, 1976-1979. Assistant Chief of Navigation Operations. Planned and executed sediment removal operations, Portland District and North Pacific Division. Responsible for sedimentation studies of Pacific Northwest navigation projects.

Engineering Geologist - USDA, Forest Service, Region 6, 1979-present. Regional Geologist. Responsible for program development, management and evaluation of Region 6 geology support to engineering and timber management operations.

Professional Affiliations - Association of Engineering Geologists; Society of Military Engineers; Sigma Xi

Publications -

Watershed Workplans, PL 566 SCS, 1961 - 1970
- Wolf Creek Watershed
- North Powder River Watershed
- Middle Fork Hood River Watershed
- Sutherlin Creek Watershed
- McKay - Rock Creek Watershed

Geology at Sawtooth Volcano, Oregon, Ore Bin, September 1969

Engineering Geology Report, North Fork Bull Run Landslide, Forest Service Mt. Hood NF, 1973

Publications (continued)

Geotechnical Engineering Section Organization and Procedures, Forest Service, Mt. Hood NF, 1975

Dredging Operations Evaluation and Report, Dredges BIDDLE and ESSAYONS Columbia River at the Mouth, 1977, U.S. Army Corps of Engineers, Portland District

Damage Control Procedures for Hopper Dredges, U.S. Army Corps of Engineers, North Pacific Division, 1979

BIOGRAPHY - John R. Pruitt

Education

B.S., Civil Engineer, 1960, New Mexico State University
Post Graduate work, Public Administration, Lewis and Clark College.

Registered Professional Engineer (New Mexico 4242)

Experience

1973-	Assistant Director, Engineering - Transportation Facilities, Pacific Northwest Region, Forest Service, Portland, Oregon.
1972-1973	Assistant Director, Engineering - Technical Services, Intermountain Region, Forest Service, Ogden, Utah.
1970-1972	Chief of Preconstruction - Transportation Facilities, Pacific Southwest Region, Forest Service, San Francisco, California.
1968-1970	Forest Engineer, Cibola National Forest, Southwestern Region, Forest Service, Albuquerque, New Mexico.
1967-1968	Assistant Forest Engineer, Cibola National Forest.
1963-1967	Civil Engineer, Carson National Forest, Southwestern Region, Forest Service, Taos, New Mexico.
1960-1963	Civil Engineer, United States Air Force, Orlando, Florida.

Awards

Quality Step Increase, 1976, for development of the Flood Emergency Road Maintenance Plan.

Forest Service representative on the Western Association of State Highways and Transportation Officials (WASHTO), Maintenance Committee, 1975-1980.

Forest Service representative to National Research Council, Transportation Research Board, Committee on Research Program, 1980.

BIOGRAPHY - John E. Steward

Education (Specializing in Geotechnical and Highway Materials Engineering)
M.S.C.E. Oregon State University, Corvallis, Oregon, 1979
B.S.C.E. Oregon State University, Corvallis, Oregon, 1965

Professional Experience

1976-	Leader, Engineering Soils and Materials Group, Engineering-Technical Services, U.S. Forest Service, Portland, Oregon
1972-1976	Soils Engineer, Engineering, U.S. Forest Service, Regional Office, Portland, Oregon
1970-1972	Materials Engineer, Umpqua National Forest, U.S. Forest Service, Roseburg, Oregon
1969-1970	Graduate Fellow at Oregon State University, U.S. Corps of Engineers, Portland District
1968-1969	Teaching Assistant and Graduate Student, Oregon State University, Corvallis, Oregon
1965-1968	Graduate Engineer, CH_2M-Hill, Consultants, Corvallis, Oregon

Technical and Professional Societies
American Society for Testing and Materials (ASTM)
American Society of Civil Engineers (ASCE)
Society of American Value Engineers (SAVE)
Sigma Tau

Professional Registration
Registered Professional Engineer (Civil), Oregon

Awards
"The Dr. L. I. Hewes Award" for "Outstanding Contributions to Highway Development," June 1977 by Western Association of State Highway and Transportation Officials.

Technical Publications
"Prediction of Pore Water Pressures Developed During the Construction of an Earth Fill Dam," 1970, Master of Sciences Thesis, Oregon State University.

"Use of Woven Plastic Filter Cloth as a Replacement for Graded Rock Filters," August 1975, 26th Annual Highway Geology Symposium, Coeur d'Alene, Idaho.

"Fabric Retaining Wall, Olympic National Forest," A Report, March 1977, U.S. Forest Service, Portland, Oregon, co-authored with John Mohney.

"The Use of Fabrics in Forest Service Road Construction," October 1977, presented at Annual Meeting of AASHTO, Atlantic City, New Jersey, co-authored with Adrian Pelzner.

Technical Publications (continued)

"Guidelines for Use of Fabrics in Construction and Maintenance of Low-Volume Roads," A Report, June 1977, U.S. Forest Service, Portland, Oregon, co-authored with Ron Williamson and John Mohney.

"Construction and Observation of Fabric Retained Soil Walls," April 1977, International Conference on the Use of Fabrics in Geotechnics, Paris, France, co-authored with J. R. Bell.

BIOGRAPHY - Gerald W. Swank

Education: West Virginia University, B.S. Forest Management, 1955

Applicable Training: Water Law Short Course (Linfield); Analytical Tools (Oregon State University; Colorado State University); Water Quality Analysis (EPA, Linn-Benton Community College); Water Quality Statistic (EPA); Hydrologic Processes (University of Washington, Oregon State University, USDA Correspondence School); numerous university-sponsored symposiums, seminars, and professional society workshops.

Experience: <u>1977 - Present</u>
Regional Water Group Leader in Portland, Oregon, with the responsibilities of: (1) developing water policy and programs (2) technical hydrology leadership, (3) coordination and service within Forest Service and external agencies for 19 Forests in Oregon and Washington.

<u>1966 - 1977</u>
Regional hydrologist in Portland, Oregon, with the responsibilities of providing technical leadership in water quality and quantity for 19 Forests in Oregon and Washington.

<u>1963 - 1966</u>
Forest hydrologist on Snoqualmie Forest in Seattle, Washington, with responsibilities of providing on-the-ground technical assistance in all water-related matters.

<u>1961 - 1963</u>
Timber Inventory Project Leader on the Ochoco Forest in Prineville, Oregon. Responsible for conducting the 10-year timber inventory and developing the management plan.

<u>1957 - 1961</u>
Various timber, soil, water, fire, and engineering-related jobs on the Big Summit District of the Ochoco Forest.

<u>1955 - 1957</u>
Captain, U.S. Air Force - Training Officer

<u>1955</u>
Cartographer, U.S. Army Map Service in Washington, D.C.

<u>1950, '53, '54, & '55 - Summers</u>
Surveyor with private Civil Engineering Firm in Alexandria, Va.

<u>1951, '52 - Summers</u>
Fire guard and erosion control crew member of the Sequoia and St. Joe Forests in California and Idaho.

Publications, Awards, Societies:

Awards

Board of Governors Scholarship - West Virginia University
Performance Award - 1976
Performance and Special Cash Award - 1972

Societies

Society of American Foresters
Arnold Air Society
Phi Epsilon Phi
Xi Sigma Pi

Publications

Water Temperatures in Steamboat	1971
Douglas-fir Supply Study	1969
Water Yield Improvements Potentials to Ochoco Reservoir	1969
Forest Land Use and Streamflow in Central Oregon	1970
Snow Fencing to Redistribute Snow Accumulation	1970

Plants observed Growing in Mount St. Helen's Area

Grass

Intermediate wheatgrass - Agropyron intermedium
Kentucky Bluegrass - Poa pratensis

Ferns

Sword Fern - Polystichum munitum
Bracken Fern - Pteridium aquilinum

Forbs

Canada thistle - Cirsium arvense
Tansy Ragwort - Senecio jacobaea
Oregon Oxalis - Oxalis oregana
Coltsfoot - Petasites speciosa
Bleedingheart - Dicentra formosa
Pearly everlasting - Anaphalis margaritacea
Insideout flower - Vancouveria hexandra
Common western strawberry - Fragaria cuneifolia
Buckhorn plantain - Plantago lanceolata
Fireweed - Epilobium angustifolium
Western hawkweed - Hieracium albertinum
Lupine - Lupinus spp.

Shrubs

Tall Oregongrape - Berberis aquifolium
Thimbleberry - Rubus parviflorus
Trailing Blackberry - Rubus ursinus
Vine maple - Acer circinatum
Salal - Gautheria shallon

Trees

Silver Fir - Abies amabilis
Douglas Fir - Pseudotsuga menziesii
Red Alder - Alnus rubra

BASIN SUMMARY

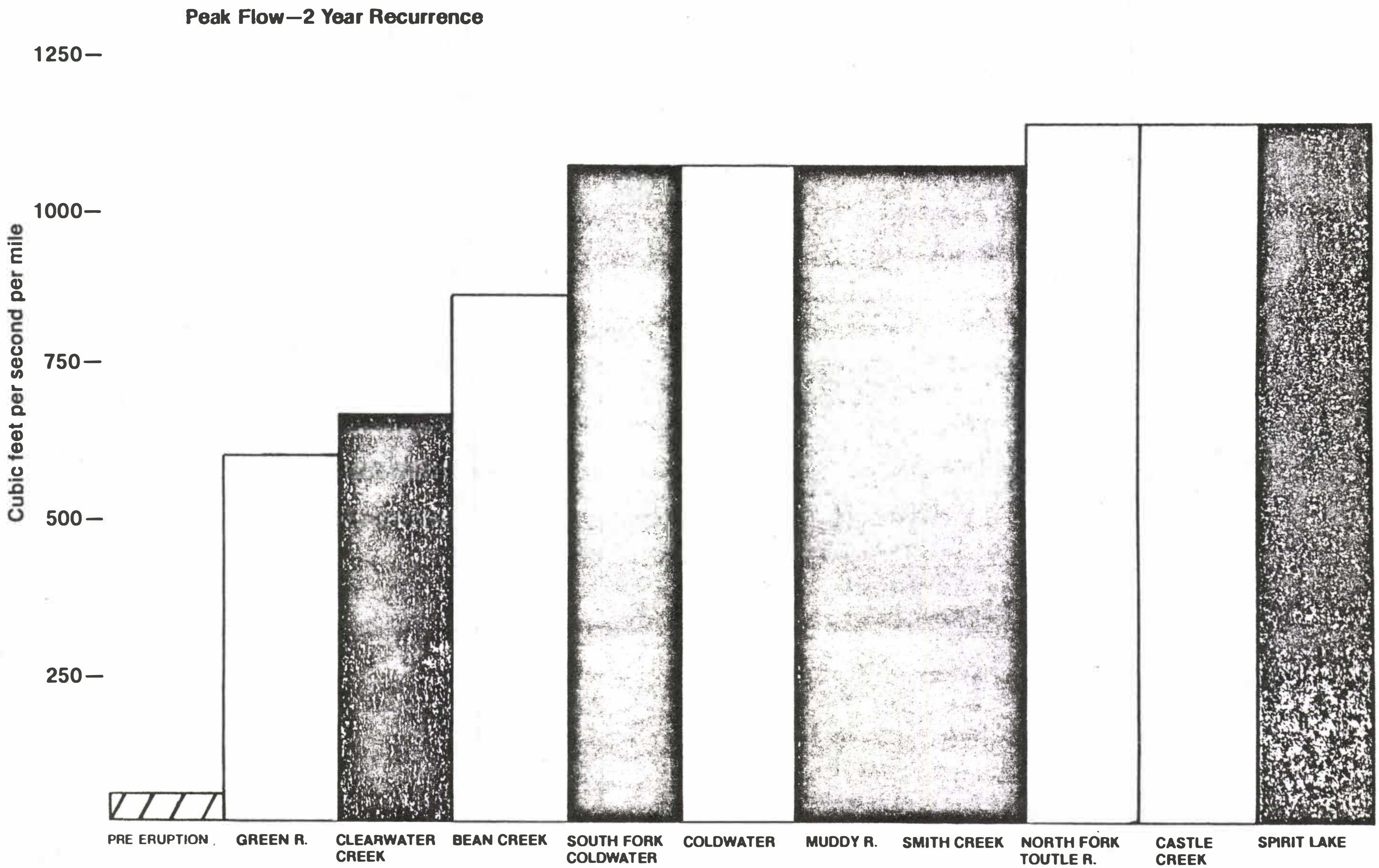
Basin	Size (sq.mi.)	Annual Runoff (Ac.Ft.) Ave.	Annual Runoff (Ac.Ft.) 100 Yr.	Peak runoff (c.s.m.) Ave.	Peak runoff (c.s.m.) 100 Yr.
1. North Toutle 1/	20.34	97,600	156,200	1,130	2,900
a. Castle @ dam	3.10	14,900	23,800	1,130	2,900
b. S. Coldwtr. @ dam	5.57	20,700	33,100)		
			)	1,060	2,750
c. Coldwater @ dam	11.77	43,700	69,900)		
d. Spirit Lake @ dam	16.13	77,400	123,800	1,130	2,900
		254,300	406,800		
2. Green River @ Forest Boundary	38.37	112,500	180,000	590	1,670
3. Muddy 2/	23.46	112,600	180,200	1,060	2,750
a. Clearwater	30.64	96,300	154,100	660	1,840
b. Bean	8.15	34,900	55,800	850	2,280
c. Smith	23.55	101,000	161,600	1,060	2,750
		457,300	731,700		
4. Pine/Swift	50.75	243,600	389,800	45	90
5. Kalama	8.34	44,300	70,900	60	90
6. S. Toutle 3/	6.47	31,100	48,200	1,130	2,900

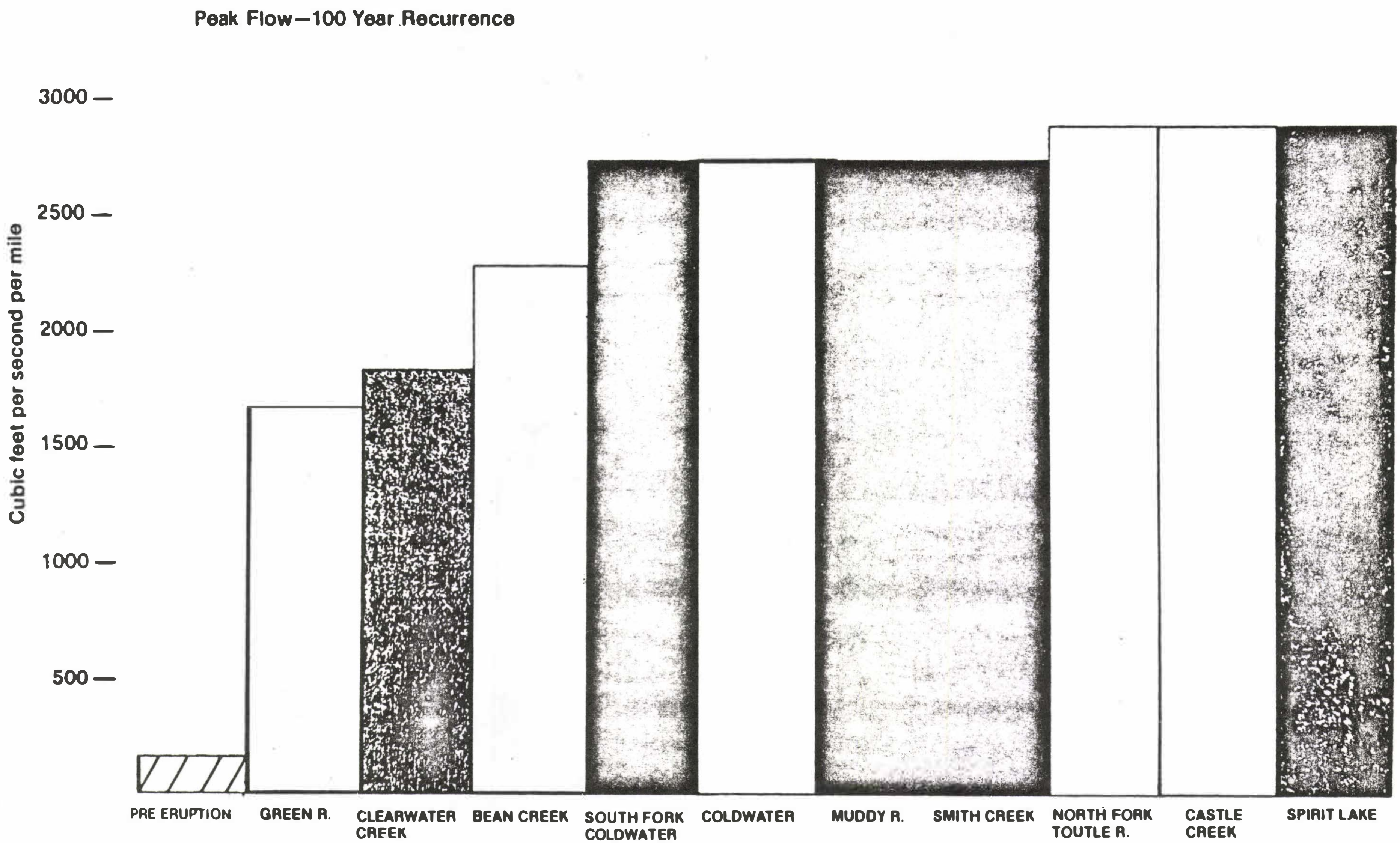
1/ Exclusive of the sub-basins shown; lower boundary at Section 11 below Forest boundary.

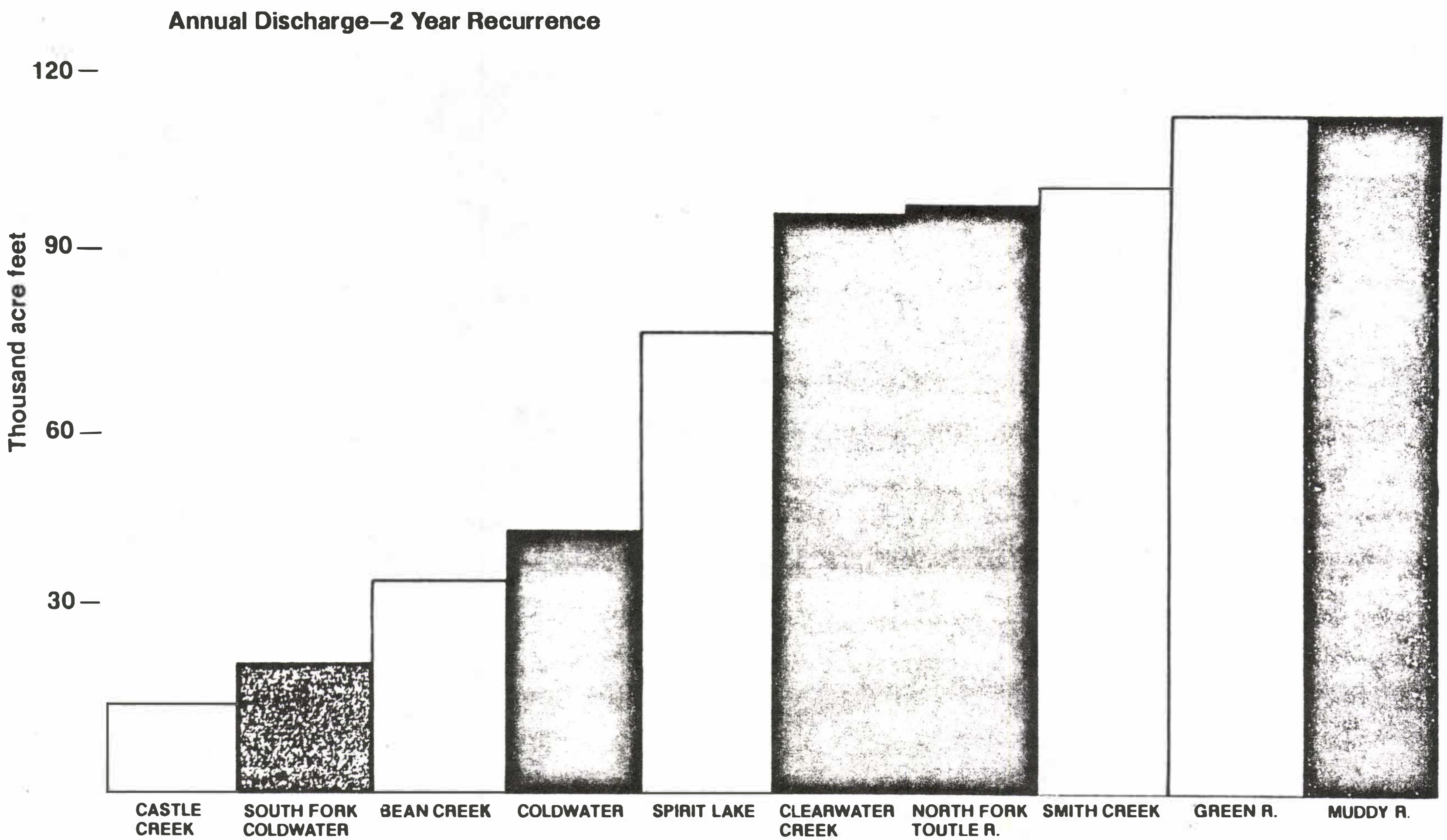
2/ Exclusive of sub-basins shown and Clear Creek; lower boundary at junction with Lewis River.

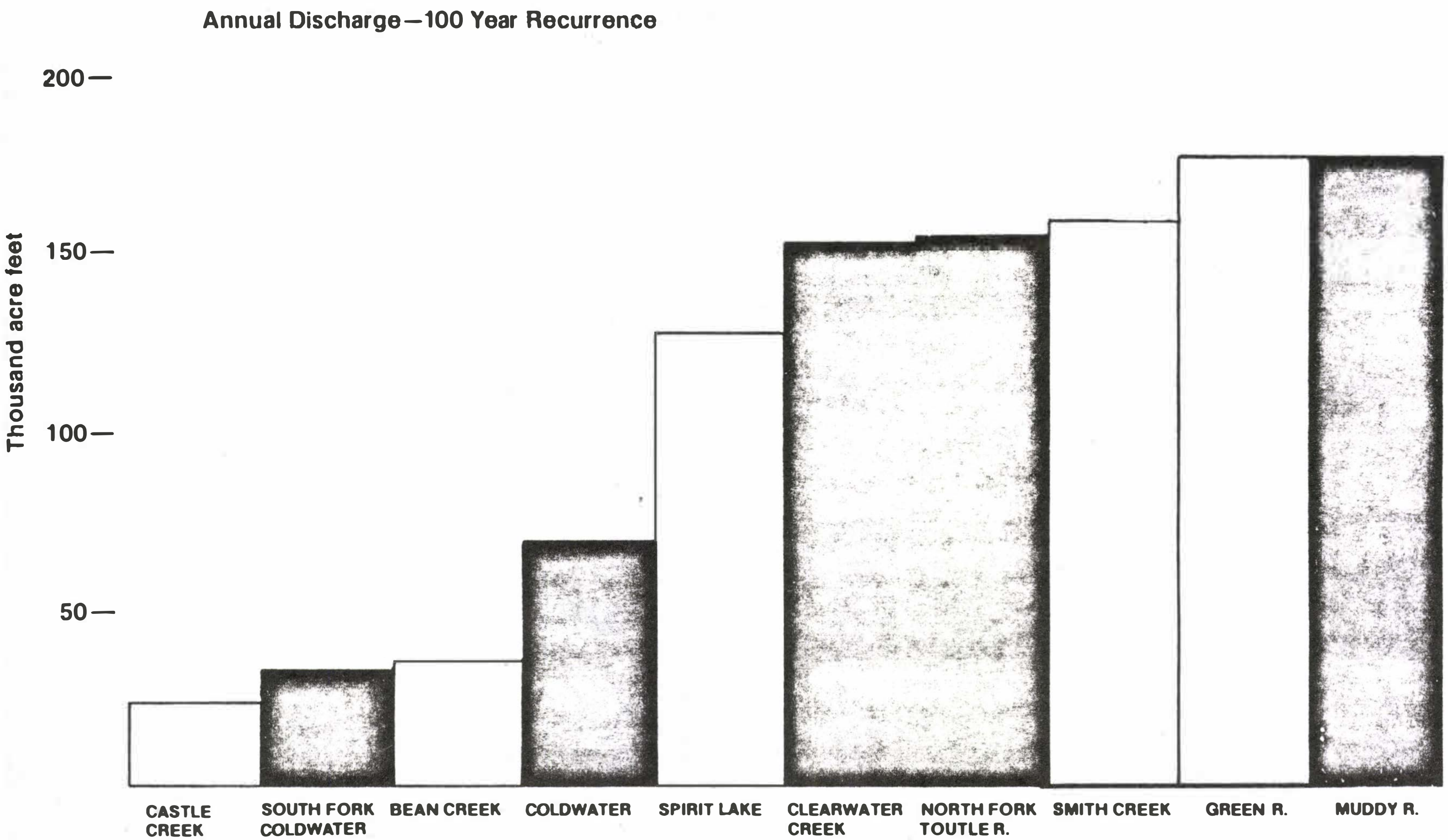
3/ Lower boundary in Section 3 below Forest boundary.

NOTE: The peak runoff shown in cubic feet per second per square mile (c.s.m.) is only applicable for small basins less than about 3 square miles and should not be applied to larger basins. Peak runoff shown is a weighted average for each basin based on cover. The Pine, Swift, and Kalama basin peak flows are based on measured pre-eruption flows with no changes predicted.


Peak Flow—2 Year Recurrence
Cubic feet per second per mile
1250
1000
750
500
250
PRE ERUPTION
GREEN R.
CLEARWATER CREEK
BEAN CREEK
SOUTH FORK COLDWATER
COLDWATER
MUDDY R.
SMITH CREEK
NORTH FORK TOUTLE R.
CASTLE CREEK
SPIRIT LAKE


Peak Flow—100 Year Recurrence
Cubic feet per second per mile
3000
2500
2000
1500
1000
500
PRE ERUPTION
GREEN R.
CLEARWATER CREEK
BEAN CREEK
SOUTH FORK COLDWATER
COLDWATER
MUDDY R.
SMITH CREEK
NORTH FORK TOUTLE R.
CASTLE CREEK
SPIRIT LAKE


Annual Discharge—2 Year Recurrence
120
90
60
30
Thousand acre feet
CASTLE CREEK
SOUTH FORK COLDWATER
BEAN CREEK
COLDWATER
SPIRIT LAKE
CLEARWATER CREEK
NORTH FORK TOUTLE R.
SMITH CREEK
GREEN R.
MUDDY R.


Annual Discharge—100 Year Recurrence
200
150
100
50
Thousand acre feet
CASTLE CREEK
SOUTH FORK COLDWATER
BEAN CREEK
COLDWATER
SPIRIT LAKE
CLEARWATER CREEK
NORTH FORK TOUTLE R.
SMITH CREEK
GREEN R.
MUDDY R.

APPENDIX

HYDROLOGIC DATA SUMMARY

I. RAINFALL INTENSITIES (Inches)

Intensity	Recurrence Interval (yrs.) 2	5	10	25	50	100
30 minutes	.35	.5	.6	.6	.75	.75
6 hours	1.8	2.3	2.6	2.9	3.2	3.5
24 hours	4.5	5.7	6.5	7.5	8.5	9.0

II. MAXIMUM PEAK FLOWS (CFS) 1/

River	Drainage Area (sq. mi.)	Recurrence Interval (yrs.) 2	5	10	25	50	100
S. Fk. Toutle	118	4,856 (41)	6,046 (51)	6,799 (58)	7,724 (65)	8,399 (71)	9,063 (77)
Pine Cr.	21.4	781 (36)	1,048 (49)	1,223 (57)	1,440 (67)	1,601 (75)	1,761 (82)
Muddy R.	136	5,175 (38)	6,844 (50)	7,820 (57)	8,931 (66)	9,683 (71)	10,378 (76)
Toutle	474	14,212 (30)	19,648 (41)	23,372 (49)	28,216 (59)	31,923 (67)	35,715 (75)
Kalama	201	8,503 (42)	10,428 (52)	11,653 (58)	13,162 (65)	14,265 (71)	15,356 (76)
Chambers Cr.	5.25	217 (41)	289 (55)	349 (66)	437 (83)	515 (98)	603 (115)
Skate Cr. Tri. #2	1.82	96 (53)	155 (85)	220 (121)	348 (191)	491 (270)	692 (380)
Skate Cr.	1.22	59 (49)	93 (76)	120 (99)	161 (132)	198 (162)	240 (197)
Quartz Cr.	1.48	86 (59)	123 (83)	151 (102)	193 (130)	228 (154)	268 (181)
Swift Cr.	26	1,196 (46)	1,591 (61)	1,798 (69)	2,010 (77)	2,139 (82)	2,249 (86)
Big Creek	13.2	397 (30)	614 (46)	771 (58)	981 (74)	1,145 (87)	1,315 (100)
Kalama R.	37.4	2,141 (57)	2,595 (69)	2,833 (76)	3,082 (82)	3,238 (87)	3,376 (90)

1/ From measured streamflow; computed by Pearson III.

Figures in parenthesis are in C.S.M.

III. Predicted Maximum Peak Flows (CSM)

	RUNOFF CURVE NUMBER (RCN) *			Measured **
Recurrence Interval (yrs.)	90	80	60	(Ave.)
2	1260 CSM	600 CSM	65 CSM	48
5	1700 "	870 "	140 "	~~66~~
10	2200 "	1200 "	210 "	82
25	2600 "	1300 "	300 "	106
50	3000 "	1600 "	400 "	130
100	3200 "	1700 "	450 "	159

IV. Current Streamflow

Stream	Flow (cfs)	Date
Coldwater	20	7/11/80
Clearwater (below Ghost Lake)	10	7/17/80
Smith (above Clearwater)	25	7/17/80
Green River (above Grizzly Creek)	7	7/17/80
S. Fork Toutle	60	7/17/80

* RCN 90 - Heavy blast area where all cover (stumps, trees, etc.) and much of the soil was blown away.

RCN 80 - Blow down area where timber was blown down, ground cover vegetation blown away, but where down timber is wind rowed on the ground and ash deposited on top of down timber.

RCN 60 - Blow down area and scorched area where existing ground cover is essentially undisturbed but an ash deposit on the existing ground cover exists.

All runoff curve numbers were computed for hydrologic soil group "B", storm type I and anticedent moisture condition III.

** An average for 6 gaged stations.

V. PRECIPITATION

Date	Precipitation (in.)		
	Glenoma 1W	Randle 1E	Cougar 6E
5-21	.08		
22	.10	.05	.94
23	.21		.52
25	.09		
26	.51		.46
27	.41	.73	.29
28	.16		.07
29			.13
Monthly Total	1.56	.78	2.41
6-1	.12		
2	.47	.39	
3	.30	.15	
5	.01		
6	.11	.04	.08
7	.03	.06	
8	.14	.18	
9	.02		.02
11	.01		.02
12			.21
13	.20		.36
14	.03		
15	.03	.14	
17	.32	.12	.05
18		.01	
20	.13		.04
23		.05	.09
24	.07	.09	.14
25	.70	.70	.86
26	.12	.07	.05
27	.15	.22	.10
28	.02		
Monthly Total	2.98	3.00	2.02
7-3		.12	
4	.51		
5	.09		
10		.05	
12	.05		
14	.03		
15	.04		
Monthly Total	.72	.17	-0-
Grand Total	5.26	3.95	4.43

APPENDIX

HYDROMETEOROLOGICAL SITES

Stream Gaging Stations

Station	Agency	Remarks
Toutle near Silver Lake	USGS	Planned for reestablishment and telemetry
Toutle near Hwy 99	"	Existing - telemetered
N. Fork Toutle near Elk Rock	"	Planned; telemetry
N. Fork Toutle near Kid Valley	"	Stage warning; telemetered
S. Fork Toutle near Camp 12	"	Stage warning; telemetered; proposed for continous flow
Pine Creek	"	Stage warning telemetered
Swift Creek	"	Proposed stage warning; telemetry
Muddy River	"	Stage warning; telemetered
Spirit Lake	"	Stage warning; telemetered
Swift Reservoir	"	Stage warning; telemetered

Additional stream gaging stations (including crest stage gages) that have been /or are currently in operation are shown elsewhere is the Appendix.

Precipitation

Station	Agency	Remarks
Glenoma 1W	National Weather Service (NWS)	Cooperator read
Randle 1E	"	Cooperator read
Cougar GE	"	" "
Vanson Pk.	(NWS) River Forecast Center	Planned; telemetry
N. Fork Toutle	"	" "
S. Fork Toutle	"	" "
St. Helens Area (2 stations)	USFS	Planned fire weather; telemetry

Snow Measurements

Station	Agency	Remarks
Lone Pine Shelters	SCS	Telemetered
Spencer Meadows	"	Planned
Surprise Lakes	"	Telemetered
Plains of Abraham	"	Planned for reestablishment; telemetry
Ryan Lake	"	" " "
Goat Marsh	"	" " "
Marble Mt.	"	Planned to convert aerial marker to telemetry

All telemetered snow sites will also measure precipitation which will be periodically telemetered.

APPENDIX

CRITICAL DISTANCE (FT) OF EXPOSED SOIL

CLAYS AND FINE TEXTURED LOAMS
PRECIP: 30-MINUTE INTENSITIES (INCHES)

Slope (%)	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
2	641	481	385	321	275	241	214	192	175	160
5	221	165	132	110	95	83	74	66	60	55
10	99	74	59	49	42	37	33	30	27	25
15	62	47	37	31	27	23	21	19	17	16
20	45	34	27	23	19	17	15	14	12	11
25	35	27	21	18	15	13	12	11	10	9
30	29	22	18	15	13	11	10	9	8	7
35	25	19	15	13	11	9	8	8	7	6
40	22	17	13	11	9	8	7	7	6	6

This is a summary table of the recommended spacing along a slope between sediment trapping measures (logs, contour ditches, drift fences, etc.). For more detail reference: "Guidelines for Computing Quantified Soil Erosion Hazard and On-Site Soil Erosion", by D. A. Anderson, USDA Forest Service, Southwestern Region, October, 1969.

Silt Fences

Silt fences should be preassembled structures specifically designed for control of sediment runoff.

The typical preassembled structure is shown in Figure A. The fabric traps the sediment, allowing the water to escape while the netting, tie cords, and posts support the fabric. Due to the corrosive nature of the fine ash, the posts shall be wood, and the top and bottom cords shall be a plastic material. The wood posts, metal fasteners, plastic fabric, netting, and cord shall be treated to resist rotting, corrosion, and ultraviolet deterioration.

Since this is a new application of silt fences, some experimenting with the placement and spacing of the fences in the field will be required.

Basic Guidelines:

1. A continuous length of 100 to 200 feet along the contour with spacing (up and down slope) between fences of:

Slope (s) %	Distance (d) feet
5	221
10	99
15	62
20	45
25	35
30	29

2. Adjacent silt fence sections should overlap (along the contour) one half the spacing between silt fence rows.

3. Ends of silt fences (10 to 20 feet) should be turned uphill so ground level at ends is within 0.5 foot in elevation of the top of the fence in its midsection.

4. Anchor end posts with cord and ground peg.

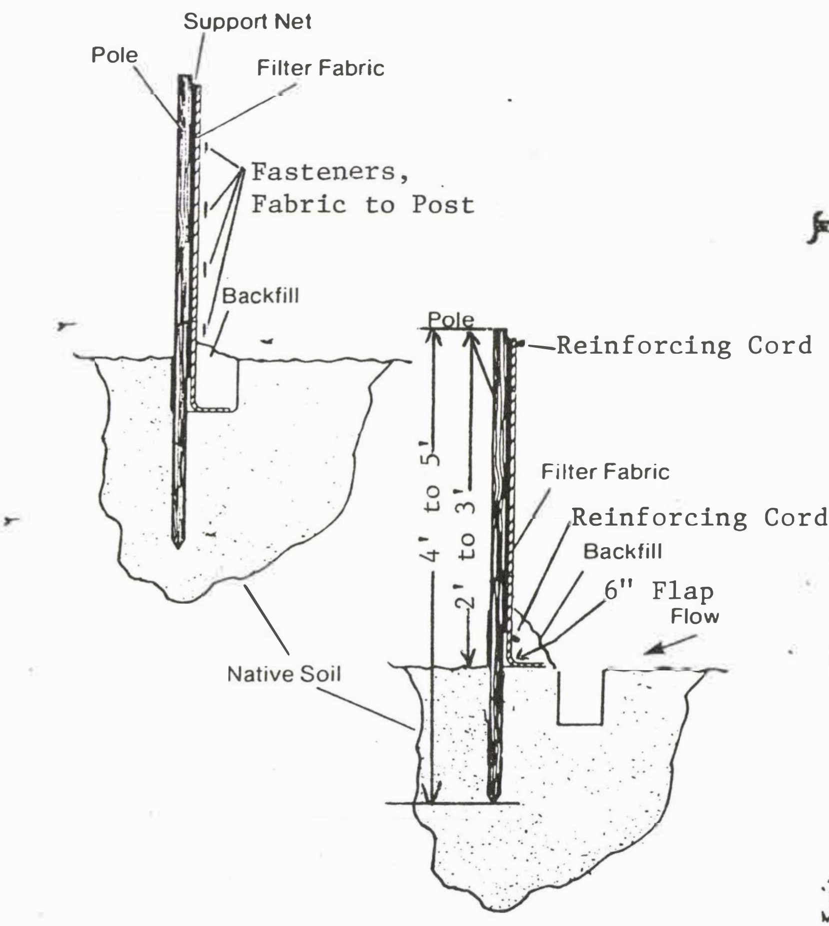
5. Use on slopes flatter than 30% in areas without woody debris to trap sediment, as indicated in recommendations.

6. A minimum of two rows of silt fencing up the slope with the lowest fence adjacent to, but above, the flood plain.

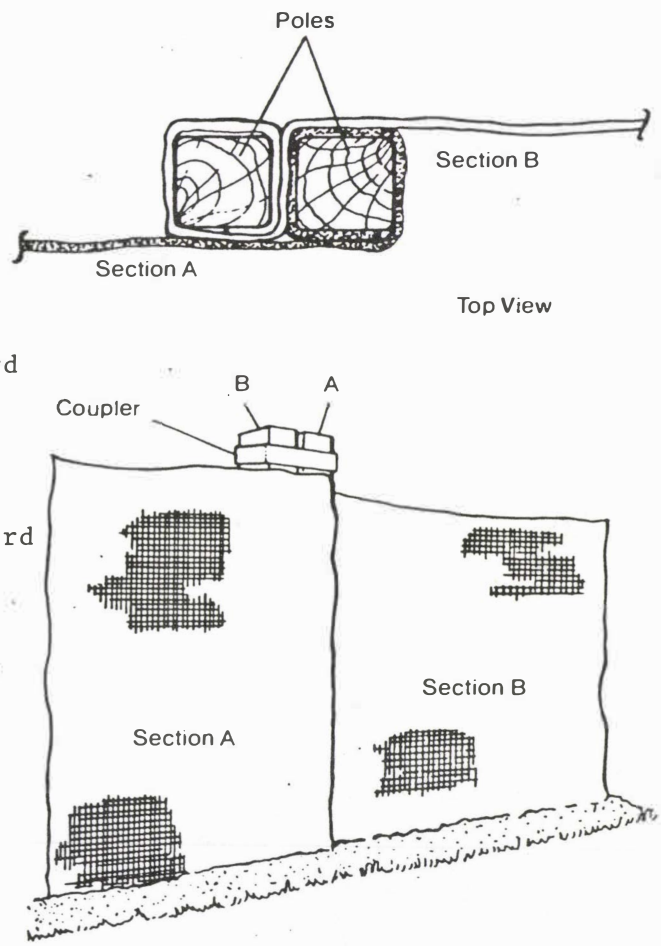
7. Post spacing and fabric strength should be selected to support the loads without bending of posts or sagging and stretching of fabric.

8. Filter fabric should be a woven fabric stabilized to resist ultraviolet light with the following minimum properties:

Grab Tensile Strength (minimum)	120 lbs.
Mullen Burst Strength	200 lbs.
Water Permeability Coefficient (k)	0.004 cm./sec.
Opening Size (E.O.S.)	40 to 80 sieve



Toe-in Methods



Joining Fence Sections

Figure A - Preassembled Silt Fence

APPENDIX

Coldwater Creek South Coldwater Creek

Drainage area = 11,320 acres (10,898)*

Slope Length		Slope Gradient (%)	Cover Condition	% Area
1.	1000	70	No Cover	5
2.	1000	40	No Cover	10
3.	500	30	No Cover	10
4.	1000	70	Minor Cover	30
5.	500	60	No Cover	5
6.	1000	70	Blasted Slopes	35
7.	1000	10	No Cover	5

Sediment delivery index = .05

	Gross Erosion		SDI		Del. Sed./Ac.	No Acres	Total (Tons)
1.	7278	x	.05	=	364	566	206,024
2.	3244	x	.05	=	162	1132	183,384
3.	1345	x	.05	=	67	1132	75,844
4.	2911	x	.05	=	146	3396	495,816
5.	3916	x	.05	=	196	566	110,936
6.	2647	x	.05	=	132	3962	522,984
7.	270	x	.05	=	14	566	7,924
							1,602,912

801 acre-feet

* Acres shown in parenthesis are revised acres.

Volcanic Ramp

Drainage area = 13,012 acres (13,018)*

Slope Length	Slope Gradient (%)	Cover Condition	% Area
50	60	No Cover	10
1,000	10	No Cover	50
1,000	40	No Cover	40

Sediment delivery coefficient = .04 (this delivery coefficient will most likely increase over-time)

Gross Erosion	SDI	Del. Sed./Acre	No. Acres	Total (Tons)
5242	.04	209	1302	272,118
526	.04	21	6509	136,689
4320	.04	173	5207	900,811
				1,309618

655 acre-feet

* Acres shown in parenthesis are revised acres.

Spirit Lake

Drainage area = 8860 acres (excluding lake surfaces)

Slope Length	Slope Gradient (%)	Cover Condition	% Area
1. 1000	5	No Cover	15
2. 1000	80	No Cover	30
3. 1000	70	Minor Cover	20
4. bare rock surfaces - no appreciable erosion			
5. 1000	20	No Cover	15

Sediment delivery index = .10

Gross Erosion	SDI	Del. Sed./Ac.	No. Acres	Total (Tons)
1. 85	.10	9	1329	11961
2. 6448	.10	645	2658	1714410
3. 2194	.10	219	1772	388068
4. 0			1772	0
5. 1084	.10	108	1329	143532
				2257971

1129 acre-feet

Castle Creek

Drainage area = 1984 acres

Slope Length	Slope Gradients (%)	Cover Condition	% Area
1. 1000	70	No Cover	20
2. 1000	70	Cover	20
3. 1000	60	No Cover	40
4. 500	70	No Cover	10
5. 500	10	No Cover	5
6. 500	40	No Cover	5

Sediment delivery index = .12

Gross Erosion	SDI	Del. Sec./Acre	No Acres	Total (Tons)
1. 7807	.12	937	397	371989
2. 1952	.12	234	397	92898
3. 6367	.12	764	794	606616
4. 5151	.12	618	198	122364
5. 205	.12	25	99	2475
6. 2296	.12	276	99	27324
				1223666

612 acre-feet

Lower Green River

Drainage area = 3070 acres 1/

Slope Length	Slope Gradient (%)	Cover Condition	% Area
1. 1000	10	Some Cover	20
2. 800	20	Some Cover	10
3. 1000	60	Some Cover	40
4. standing dead timber - no appreciable erosion			

Sediment delivery index = .02

Gross Erosion	SDI	Del. Sed./Acre	No. Acres	Total
1. 63	.02	1	614	614
2. 212	.02	4	307	1302
3. 1376	.02	28	1228	34384
4.			921	0
				36300
				18 acre-feet

Upper Green River

Drainage area = 9660 acres 1/

Slope Length	Slope Gradient (%)	Cover Condition	% Area
1. 800	10	Some Cover	10
2. 1000	70	Cover	20
3. 500	40	Cover	20
4. 1000	30	Cover	10
5. 1000	10	No Cover	20
6. Timbered - no appreciable erosion			20

Sediment delivery coefficient = .03

Gross Erosion	SDI	Del. Sed./Acre	No. Acres	Total
1. 58	.03	2	966	1932
2. 1753	.03	53	1932	102396
3. 516	.03	15	1932	28980
4. 491	.03	15	966	14490
5. 65	.03	2	1932	3864
6.			1932	0
				151662
				76 acre-feet

1/ Acres above potential impoundment sites.

Lower Bean Creek

Drainage area = 4256 acres

	Slope Length	Slope Gradient (%)	Cover Condition	% Area
1.	1000	20	No Cover	10
2.	1000	60	Some Cover	5
3.	1000	60	No Cover	5
4.	1000	40	No Cover	15
5.	bare rock - no erosion			5
6.	1000	70	Cover	45
7.	1000	70	No Cover	15

Sediment delivery coefficient = .06

	Gross Erosion	SDI	Del. Sed./Acre	No. Acres	Total (Tons)
1.	1160	.06	70	426	29820
2.	6582	.06	395	213	84135
3.	1646	.06	99	213	21087
4.	3598	.06	216	638	137808
5.	0	.06	0	213	0
6.	2018	.06	121	1915	231715
7.	8071	.06	484	638	308792
					813357

407 acre-feet

Upper Bean Creek

Drainage area = 960 acres

	Slope Length	Slope Gradient (%)	Cover Condition	% Area
1.	1000	60	No Cover	30
2.	1000	60	Cover	30
3.	1000	20	Cover	40

Sediment delivery coefficient = .10

	Gross Erosion	SDI	Del. Sed./Ac.	No. Acres	Total (Tons)
1.	6150	.09	554	288	159552
2.	1538	.09	138	288	39744
3.	271	.09	24	384	9216
					108512

104 acre-feet

Smith Creek

Drainage area = 15072 acres

Slope Length	Slope Gradient (%)	Cover Condition	% Area
1. 500	80	No Cover	10
2. 1000	30	No Cover	20
3. 1000	60	No Cover	15
4. 1000	60	Cover	10
5. 1000	70	Cover	20
6. 1000	70	No Cover	5
7. 1000	40	No Cover	20

Sediment delivery index = .09

Gross Erosion	SDI	Del. Sed./Acre	No. Acres	Total (Tons)
1. 6672	.09	600	1507	904200
2. 2410	.09	217	3014	654038
3. 7014	.09	631	2261	1426691
4. 1754	.09	158	1507	238016
5. 2150	.09	194	3014	584716
6. 319	.09	27	754	20358
7. 3834	.09	345	3014	1039830
				4867849

2434 acre-feet

Clearwater Creek

Drainage area = 19610 acres

	Slope Length	Slope Gradient (%)	Cover Condition	% Area
1.	1000	10	Cover	15
2.	1000	10	No Cover	10
3.	standing timber - no appreciable erosion			
4.	1000	60	Cover	15
5.	1000	60	No Cover	10
6.	1000	30	Cover	15
7.	1000	30	No Cover	10

Sediment delivery coefficient = .03

	Gross Erosion	SDI	Sel. Sed./Acre	No. Acres	Total (Tons)
1.	72	.03	2	2942	5884
2.	290	.03	9	1961	17649
3.	0	.03	0	4903	0
4.	1592	.03	48	2942	141216
5.	6367	.03	191	1961	374551
6.	547	.03	16	2942	47072
7.	2188	.03	66	1961	129426
					715,798

358 acre-feet

Modified Soil Loss Equation

The modified soil loss equation is as follows:

$$A = R\ K\ LS\ VM$$

where:

A = estimated average soil loss per unit area in tons/acre for the time period selected for R (usually 1 year). It is not intended to reflect climatic extremes of a given year.

R = rainfall factor, usually expressed in units of the rainfall - erosivity index, EI, and evaluated from an iso-erodent map.

K = soil erodibility factor, usually expressed in tons/acre/energy-intensity units for a specific soil in cultivated continuous fallow tilled up and down slope.

L = slope length factor is the ratio of soil loss from the field slope length to that from a 72.6 foot length on the same soil, gradient cover, and management.

S = slope gradient factor is the ratio of soil loss from a given field gradient to that from a 9-percent slope with the same soil, cover, and management.

VM = vegetation management factor is the ratio of soil loss from land managed under specified conditions to that from the fallow condition on which the K factor is evaluated.

R Factor

The R factor is generally obtained from published maps. In areas where snowmelt is an important source of overland flow, the R factor must be modified to take this into account. Modification of the R factor for

snowmelt areas is described by Warrington (in press) and is accomplished using the following formulae:

Ra = Adjusted R factor for snowmelt areas.

Ra = Rs + R

Rs = (Xpw)1.5

Xpw = (pw)(Xp)

where:

Xp = average annual precipitation.

pw = percent of average annual precipitation occurring during winter (Dec., Jan., Feb., Mar.).

Xpw = average annual precipitation occurring during winter.

R = 35 (from published map for Mt. St. Helens area)

Xp	x	pw	=	Xpw	x	1.5	=	Rs	+	R	=	Ra
70		.55		38.5		1.5		57.75		35		93
80		.55		44.0		1.5		66.00		35		101
90		.55		49.5		1.5		74.25		35		109
100		.55		55.0		1.5		82.50		35		118
110		.55		60.5		1.5		90.75		35		126
120		.55		66.0		1.5		99.00		35		134
130		.55		71.5		1.5		107.25		35		142
140		.55		77.0		1.5		115.50		35		151

K Factor

The K factor provides an index of the detachability of a soil and is determined using several soil variables. These include: Percent sand, percent silt plus fine sand, percent organic matter, soil structure, and permeability. Values for these variables are used in a nomograph (Warrington, in press) and an appropriate K factor is extracted.

LS Factor

LS factors vary as slope gradients, slope lengths, and soil permeabilities change. These factors for complex slopes are calculated using the following formula (Warrington, 1980).

$$LS = 1/\lambda e \cdot \sum_{j=1}^{n} \left(sj\lambda j^{\,m+1} - sj\lambda j\text{-}1^{\,m(j-1)+1}\right)/72.6^{m}$$

where:

λ_e = overall slope length in feet.

j = slope segment index.

λj = length (feet) from top to lower end of any segment j.

λj_{-1} = total slope length (feet) above segment j.

sj = slope factor ($430\ s^2 + 30s + 0.43/6.574$) for s of segment j.

s = sine of slope angle in degrees.

m = exponent based on slope gradient.

LS Factors for Various Combinations of Slope Gradients and Slope Lengths

(Assumed Permeability Code = 4)

	Slope Gradient							
	10%	20%	30%	40%	50%	60%	70%	80%
100'	1.37	4.21	8.21	13.07	18.41	23.91	29.32	34.47
200'	1.94	6.38	12.45	19.80	27.90	35.23	44.44	52.24
300'	2.37	8.14	15.88	25.26	35.58	46.21	56.68	66.63
400'	2.74	9.68	18.87	30.02	42.28	54.92	67.35	79.18
500'	3.06	11.06	21.57	34.32	48.34	62.79	77.00	90.53
600'	3.36	12.34	24.07	38.29	53.93	70.05	85.90	100.99
700'	3.62	13.54	26.40	42.00	59.16	76.84	94.23	110.78
800'	3.87	14.67	28.60	45.50	64.09	83.25	102.09	120.02
900'	4.11	15.74	30.69	48.83	68.78	89.34	109.56	128.81
1000'	4.33	16.77	32.70	52.02	73.27	95.17	116.71	137.21

	Slope Gradient	
	90%	100%
100'	39.25	43.62
200'	59.49	66.12
300'	75.88	84.33
400'	90.17	100.22
500'	103.09	114.57
600'	115.01	127.82
700'	126.15	190.20
800'	136.68	151.90
900'	146.69	163.02
1000'	156.26	173.66

VM Factors

The equation

$$A = RKLS$$

gives the amount of average annual soil loss from sheet and rill erosion on an area in continuous fallow condition. Where some form of vegetative cover exists which will protect the soil from or retard erosion, the above result must be reduced accordingly. The VM factor is always a decimal fraction (or 1.00 for fallow conditions) and shows the effect of various vegetation management practices on soil loss. Procedures for determining appropriate VM factors are outlined in Warrington (in press).

Field reconnaissance in the Mt. St. Helens devastated area has shown most sheet and rill erosion to occurring on steep slopes in areas devoid of vegetation; i.e., recent clearcuts and direct blast areas. In order to obtain an indication of the amounts of soil material being moved in these areas, the MSLE was applied to various representative slope gradients and rainfall zones. An average slope length of 600-feet was assumed.

Predicted Average Annual Soil Loss by Rainfall Zones and Slope Gradient (TIA/Yr).[1/]

Inches Precip.	70	80	90	100	110	120	130	140
60	2604	2828	3052	3304	3528	3752	3976	4228
50	2008	2182	2354	2549	2722	2894	3067	3262
40	1414	1535	1657	1794	1915	2037	2158	2295
30	893	970	1046	1133	1210	1286	1363	1450
20	446	485	523	566	605	643	681	725
10	112	121	131	142	151	161	170	181

[1/] Assumed permeability code of 4.

Again it should be stressed that these figures are a projection of sheet and rill erosion at a constant rate. In reality, erosion rates may decrease over time because of surface armoring, invasion of vegetation, and lack of material available to be eroded.

Watershed	Drainage Size Acres	Drainage Size Sq. mi.	Av. Ann. Precip.	Ra Factor
Lower Green	3070	4.8	85	105.13
Upper Green	9660	15.1	90	109.25
Lower Bean	2660	4.2	110	125.75
Upper Bean	870	1.4	100	117.50
Clearwater	17400	27.2	105	121.63
Coldwater	11320	17.7	95	113.38
Spirit Lake	8860	15.9	100	117.50
Muddy River	26160	40.9	120	134.00
Castle Creek	1870	2.9	120	134.00

ALUTIN RILL EROSION METHOD

The Alutin Rill Erosion Method is a rapid means of determining the amount in tons per acre of rill erosion that has already taken place. The formula for this method is:

Soil loss (ton/acre) = Σ square inches of cross sections of rills along a measured linear distance of 13.7 feet across slope.

In the field, total cross-sectional area of rills along a 42-foot transect was measured. This total was then divided by 3 to obtain a tons per acre figure. The following data shows the amount of rill erosion that had occurred during a 6-week period (time from initial eruption to time of sample).

Table 1
Impoundment Data - Castle, Coldwater, and Spirit Lake

Site Location	Structural Height to Over Top (ft.)	Surface Area @ Overtop Elev. (ac.)	Capacity (ac. ft.)	Annual Inflow (ac. ft.)	Annual Sediment (ac. ft.)
Castle Creek T9M, R4E SW 1/4, Sec. 14	90	340	22,000	14,000	300
Coldwater Creek T9M, R4E NE 1/4, Sec. 11 NW 1/4, Sec. 12	180	1,300	171,000	84,900	1,700
Spirit Lake T9M, R5E S 1/2, Sec. 15 Sec. 22	158	3,500	440,000	76,200	465

Table 2
Channel and Gully Erosion - North Fork Toutle River System

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area--> (sq. mi.)	Sediment Delivery Ratio (%)	Annual Sediment Delivery (ac. ft.)
N. F. Toutle River 1/	18,300	580,200	50 -->	12	70,000
Castle Creek Dam	40	1,270	3.1 -->	24	300
Coldwater Creek Dam	340	10,700	17.34 -->	16	1,700
Spirit Lake Dam	90	2,900	16.13 -->	16	465
N. F. Toutle (on Forest)	1,250	48,100	16.34 -->	16	7,700

1/ Calculated to the distal end of the pyroclastic flow.

Table 3
Channel and Gully Erosion and Detention Sites - Green River System

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area (sq. mi.)	→	Sediment Delivery Ratio (%)	Annual Sediment Delivery (ac. ft.)
Green River	200	5,100	38.37	→	13	665
Lower Green Site	118	3,025	15.1	→	16	480
Upper Green Site	78	1,990	10.5	→	18	360

Site Location	Evaluated Height (ft.)	Length (ft.)	Surface Area (ac.)	Capacity (ac. ft.)	Annual Inflow (ac. ft.)	Annual Sediment (ac. ft.)
Lower Green Site T10N, R5E Sec. 11, SE 1/4	50	800	95	3,800	48,000	480
Upper Green Site T10N, R6E Sec. 17, SE 1/4	50	1,500	275	9,600	13,000	360

Table 4
Channel and Gully Erosion and Detention Sites - Clearwater System

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area (sq. mi.)		Sediment Delivery Ratio (%)	Annual Sediment Delivery (ac. ft.)
Clearwater	246	7,820	30.64	->	13	1,015
Clearwater Site	56	1,800	27	->	14	250

Site Location	Evaluated Height (ft.)	Length (ft.)	Surface Area (ac.)	Capacity (ac. ft.)	Avg. Annual Inflow (ac. ft.)	Annual Sediment (ac. ft.)
Clearwater T9M, R6E Sec. 25, NE 1/4	60	1,100	135	5,450	100,900	250

Table 5
Channel and Gully Erosion and Detention Sites - Smith/Bean Systems

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area (sq. mi.)		Sediment Delivery Ratio (%)	Annual Sediment Delivery (ac. ft.)
Smith	1,140	40,000	23.55	→	15	6,000
Bean	97	3,080	8.15	→	19	585
Bean Lower	81	2,570	4.2	→	22	565
Bean Upper	30	950	1.4	→	27	255

Site Location	Evaluated Height (ft.)	Length (ft.)	Surface Area (ac.)	Capacity (ac. ft.)	Annual Inflow (ac. ft.)	Annual Sediment (ac. ft.)
Smith T8M, R6E Sec. 9, SE 1/4	50	900	180	7,200	101,000	6,000
Bean Lower T9M, R6E Sec. 8, SE 1/4	50	650	45	1,800	17,800	565
Bean Upper T9M, R6E Sec. 8, SE 1/4	50	1,100	80	2,800	5,800	255

Table 6
Channel and Gully Erosion and Detention Sites - Muddy River System

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area→ (sq. mi.)	Sediment Delivery Ratio (%)	Annual Sediment Delivery (ac. ft.)
Muddy River	2,600	96,900	86 1/ →	10	9,700
Muddy	1,980	74,830	71 1/ →	10.5	7,900

Site Location	Evaluated Height (ft.)	Length (ft.)	Surface Area (ac.)	Capacity (ac. ft.)	Annual Inflow (ac. ft.)	Annual Sediment (ac. ft.)
Muddy T8H, R6E Sec. 23, SW 1/4	50	950	185	6,600	196,200	7,900

1/ Includes areas of Bean, Smith, and Clearwater.

Table 7
Channel and Gully Erosion - Pine System

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area→ (sq. mi.)	Sediment Delivery Ratio (%)	Annual Sediment Delivery (ac. ft.)
Pine Creek	1,434	54,100	24 →	14	7,575

Table 8
Channel and Gully Erosion - South Toutle System

Drainage	Measured Erosion 5/18 - 6/19 (ac. ft.)	Adjusted to Annual Precipitation (ac. ft.)	Drainage Area→ (sq. mi.)	Sediment Delivery Ratio (%)	Annual Dediment Delivery (ac. ft.)
South Toutle 1/	2,724	103,969	50 →	12	12,500

1/ Calculated to boundry Sec. 29-30, T9M, R3E.

APPENDIX - CHANNEL AND GULLY EROSION

1. Measured erosion sections

Green River Section G-1

T10N, R6E, Sec. 17, NE¼

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	30	1.5	45

Total cross sectional area eroded: 45 sq. ft.

Erosion rate per mile:

45 sq. ft. x 5,280 ft./mi. ÷ 43,560 sq. ft./ac. = 5.5 af./mi.

Clearwater Creek Section C-1

T9N, R6E, Sec. 25, NE¼

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	50	1.5	75

Total cross-sectional area eroded: 75 sq. ft.

Erosion rate per mile:

75 sq. ft. x 5,280 ft./mi. ÷ 43,560 sq. ft./ac. = 9 af./mi.

Bean Creek Section B-1

T9N, R6E, Sec. 8, SW¼

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1 (above culvet)	3D	3.5	147
1-A (below culvert)	24	2	48
			195 sq. ft. ÷ 2 =

Average cross-sectional area eroded: 97.5 sq. ft.

97.5 sq. ft. x 5,280 ft./mi. ÷ 43,560 sq. ft./ac. = 11.8 af./mi.

Smith Creek Section S-1

T8N, R6E, Sec. 9, NW¼

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	125	4	500
2	32	2	64
3	80	3	240

Total cross-sectional area eroded: 804 sq. ft.

Erosion rate per mile:

804 sq. ft. x 5,280 ft./mi. ÷ 43,560 sq. ft./ac. = 97.5af./mi.

South Fork Toutle River Section ST-1

T9N, R3E, Sec. 30, SE¼

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	85	3	255

Total cross-sectional area eroded: 255 sq. ft.

Erosion rate per mile:

255 sq. ft. x 5,280 ft./mi. ÷ 43,560 sq. ft./ac. = 30.9 af./mi.

Muddy River Section M-1

T8N, R6E, Sec. 23, SW¼

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	34	1.5	51
2	9	0.33	3
3	10	0.33	3.3
4	20	1.0	20
5	12	1.0	12
6	5	0.17	0.85
7	120	2.0	240
8	80	1.5	120

Total cross-sectional area eroded: 450 sq. ft.

Erosion rate per mile:

450 sq. ft. x 5,280 ft./mi. ÷ 43,560 sq. ft./ac. = 54.5 af./mi.

2. Photo interpreted sections

North Fork Toutle River Section NT-1 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	250	40	10,000
2	100	40	4,000
3	50	15	750
4	100	30	3,000
5	50	10	500
6	200	40	8,000
		Total	26,250 sq. ft./ft.
		=	3,182 at./mi.

North Fork Toutle River Section NT-2 (P)

Gully	Width	Depth	Area
1	100	40	2,000
2	250	30	7,500
		Total	9,500 sq. ft./ft.
		=	1,152 af./mi.

North Fork Toutle River Section NT-3 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	150	40	6,000
2	150	20	3,000
		Total	9,000 sq. ft./ft.
		=	1,090 af./mi.

North Fork Toutle River Section NT-4 (P)

Gully	Width	Depth	Area
1	150	20	3,000
		Total	3,000 sq. ft./ft.
		=	364 af./mi.

Grizzly Creek Section GZ-1 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	20	2	40
		Total	40 sq. ft./ft.
		=	4.8 af./mi.

Clearwater Creek Section C-1 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	35	3	105
2	50	3	150
		Total	255 sq. ft./ft.
		=	30.9 af./mi.

Clearwater Creek Section C-2 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	50	0.5	25
		Total	25 sq. ft./ft.
		=	3.0 af./mi.

Smith Creek Section S-1 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	50	10	500
2	100	3	300
3	50	5	250
		Total	1,050 sq. ft./ft.
		=	127 af./mi.

Smith Creek Section S-2 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	50	2	100
		Total	100 sq. ft./ft.
		=	12.1 af./mi.

South Smith Creek Section SS-1(P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	15	2	30
2	130	1.5	195
3	60	2	120
		Total	345 sq. ft./ft.
		=	41.8 af./mi.

Muddy River Section M-2 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	15	5	75
2	50	3	150
3	20	5	100
		Total	325 sq. ft./ft.
		=	39.4 af./mi.

Pine Creek Section P-1 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	75	10	750
		Total	750 sq. ft./ft.
		=	91 af./mi.

South Fork Toutle River Section ST-1 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	400	20	8,000
2	80	30	2,400
		Total	10,400 sq. ft./ft.
		=	1,260 af./mi.

South Fork Toutle River Section ST-2 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	300	5	1,500
2	100	2	200
		Total	1,700 sq. ft./ft.
		=	206 af./mi.

South Fork Toutle River Section ST-3(P)

Gully	Width	Depth	Area
1	10	2	20
2	15	2	30
3	20	3	60
4	20	3	60
		Total	170 sq. ft./ft.
		=	21 af./mi.

South Fork Toutle River Section ST-4 (P)

Gully	Width (ft.)	Depth (ft.)	Area (sq. ft.)
1	100	5	500
2	60	5	300
3	75	3	75
4	110	2	220
5	50	5	250
6	20	3	60
		Total	1,405 sq. ft./ft.
		=	170 af./mi.

3. Sediment Yield Calculations

(a) North Fork Toutle River Drainage

(1) Rate of loss May 18 - June 19:

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.
COE 4 to NT-1/NT-2	3,180	3.6	11,448
NT-1NT-2 to NT-2/NT-3	1,150	1.8	2,070
NT-2/NT-3 to NT-3/NT-4	1,090	1.5	1,635
NT-3/NT-4 to FSB	360	5.2	1,872
FSB to S.L. Dam	100	3.5	350
Tributaries	100	9.0	900
		Total	18,275

(2) Conversion to yearly total:

Annual precip. average N. Fork Toutle 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

18,275 = 3.15% yearly total = 580,200 af.

(3) Sediment delivery:

Drainage area 50 sq. mi.
Sediemtn delivery ratio = 12%

Annual sediment delivery @ COE 4 = 70,000 af.
= 140,000,000 tons
= 113,000,000 cy.

(b) North Fork Toutle River Drainage (on Forest)

(1) Rate of loss May 18 - June 19:

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Ramp	100	9	900
Mainstem	100	3.5	350
		Total	1,250

(2) Conversion to yearly total:

Annual precip. average N. Fork Toutle 120"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.6% average annual

1,250 = 2.6% yearly total = 48,100 af.

(3) Sediment delivery:

Drainage area = 16.34 sq. mi.
Sediment delivery ratio = 16%

Annual sediment delivered to FSB = 7,700 af.
= 15,400,000 tons
= 12,497 cy.

(c) Green River Drainages

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	5	6.2	31
Above lower ℄			118
Tributaries	10	5.0	50
		Total	199

(2) Conversion to yearly total:

Annual precip. average - Green River 80"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.9% average annual

199 = 3.9% yearly total = 5,102 af.

(3) Sediment delivery

Drainage area = 38.37 sq. mi.
Sediment delivery ratio = 13%

Annual sediment delivered @ FSB = 665 af.

= 1,330,000 tons
= 1,073,000 cy.

(d) Clearwater Creek Drainage

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem above ℄	10	3.7	37
Tributaries	20	2.2	44
Mainstem below ℄	10	1.6	16
		Total	97

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

97 = 3.15% yearly total = 3,080 af.

(3) Sediment delivery

Drainage area = 8.15 sq. mi.
Sediment delivery ratio = 19%

Annual sediment delivered 585 af.

= 1,170,400 tons
= 943,600 cy.

(e) Bean Creek Drainage

Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Above ℄	3	4.8	14
Tributaries	6	7.0	42
Mainstem to debris	30	4.0	120
Mainstem to Muddy River	50	1.4	70
		Total	246

Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Couger 6E 3.15"
= 3.15% average annual

246 = 3.15% yearly total = 7,820 af.

Sediment delivery

Drainage area = 30.64 sq. mi.
Sediment delivery ratio = 13%

Annual sediment delivered 1,015 af.

= 2,034,000 tons
1,639,000 cy.

(f) Smith Creek Drainage

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
South Smith Creek	40	2.3	92
Smith Creek	10	3.0	30
Smith Creek	130	3.0	390
Tributaries	60	9.0	540
		Total	1,142

(2) Conversion to yearly total:

Annual precip. average 110"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 7.86 average annual

1,142 = 2.86 yearly total = 40,000 af.

(3) Sediment delivery

Drainage area = 23.55 sq. mi.
Sediment delivery ratio = 15%

Annual sediment delivered = 6,000 af.

= 12,000,000 tons
= 9,678,000 cy.

(g) Muddy River Drainage

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Muddy River	90	6.5	585
Muddy River above ℄			1,983
		Total	2,568

(2) Conversion to yearly total:

Annual precip. average 120"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.65% average annual

2,568 = 2.65% yearly total = 96,905 af.

(3) Sediment delivery

Drainage area = 86 sq. mi.
Sediment delivery ratio - 10%

Annual sediment delivered 9,700

= 19,400,000 tons
= 15,646,000 cy.

(h) Muddy River Drainage (Muddy only)

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Abraham	40	3.2	128
Ape	3	2.4	7
Smith	50	1.9	95
lower Muddy	50	6.5	325
		Total	555

(2) Conversion to yearly total:

Annual precip. average — 120"
Precip. May 18 - June 19 Cougar 6E — 3.15"
= 2.65% average annual

555 = yearly total = 20,943 af.

(3) Sediment delivery

Drainage area = 23.46
Sediment delivery ratio = 14%

Annual sediment delivered = 2,930 af.

= 5,860,000 tons
= 4,726,000 cy.

(i) Pine Creek Drainage

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Pine Creek	40	3.2	128
Pine Creek	40	2.8	112
Pine Creek	90	2.5	225
Pine Creek	90	6.6	594
Pine Creek	90	4.2	375
		Total	1,434

(2) Conversion to yearly total:

Annual precip. average 120"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.65% average annual

1,434 = 2.65% yearly total = 54,113 af.

(3) Sediment delivery

Drainage area = 24 sq. mi.
Sediment delivery ratio = 14%

Annual Sediment delivered 7,575 af.

= 15,152,000 tons
= 12,220,000 cy.

(j) South Fork Toutle Rive Drainage

(1) Rate of loss May 18 - June 19:

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
4-3 to ST-3/ST-2	20	5.3	106
ST-3/ST-2 to ST-2/ST-4	210	2.0	420
ST-2/ST-4 to ST04/ST-1	170	2.2	374
ST-4/ST-1 to Headwell	1,260	1.4	1,760
Tributaries	20	3.5	70
		Total	2,724

(2) Conversion to yearly total:

Annual precip. average South Fork Toutle 120"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.62% average annual.

2,724 af. - 2.62% yearly total = 103,969 af.

(3) Sediment delivery:

Drainage area = 5D sq. mi.
Sediment delivery ratio = 12%

Annual sediment delivered @ 4-3 = 12,500 af.

= 25,500,000 tons
= 20,163,000 cy.

(k) South Fork

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	1,260	0.7	882
Tributaries	20	3.5	70
		Total	952

(2) Conversion to yearly total:

Annual precip. average 120"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.62% yearly total = 36,336 af.

(3) Sediment delivery

Drainage area = 6.47
Sediment delivery ratio = 20%

Annual sediment delivered = 7,300 af.

= 14,600,000 tons
= 11,775,000 cy.

(1) Coldwater Creek Dam

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	40	4.8	192
South Coldwater	40	3.6	144
		Total	336

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

336 = 3.15% yearly total = 10,100 af.

(3) Sediment delivery

Drainage area = 17.34 sq. mi.
Sediment delivery ratio = 16%

Annual Sediment delivered = 1,700 af.

= 3,400,000 tons
= 2,700,000 cy.

(m) South Castle Creek Dam

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac.ft.)
Mainstem	40	1	40
		Total	40

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

4D = 3.15% yearly total = 1,270 af.

(3) Sediment delivery

Drainage area = 3.1 sq. mi.
Sediment delivery ratio = 24%

Annual Sediment delivered = 300 af.

= 600,000 tons
= 484,000 cy.

(n) Spirit Lake Dam

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Bear Creek	40	1.8	72
Bear Pass	5	0.6	3
Harmony	10	1.6	16
		Total	91

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

91 = 3.15% yearly total = 2,900 af.

(3) Sediment delivery

Drainage area = 16.13 sq. mi.
Sediment delivery ratio = 16%

Annual sediment delivered = 465 af.

= 930,000 tons
= 750,000 cy.

(o) Lower Green Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	5	5.6	28
Tributaries	10	9.0	90
		Total	118

(2) Conversion to yearly total:

Annual precip. average 80"
Precip. May 8 - June 19 Cougar 6E 3.15"
= 3.9% average annual

118 = 3.9% yearly total = 3,025 af.

(3) Sediment delivery

Drainage area = 15.1 sq. mi.
Sediment delivery ratio = 16%

Annual Sediment delivered = 480 af.

= 968,000 tons
= 774,000 cy.

(p) Upper Green Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	5	7.5	12
Tributaries	10	6.5	65
		Total	77

(2) Conversion to yearly total:

Annual precip. average 80"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.9% average annual

77 = 3.9% yearly total = 1,987 af.

(3) Sediment delivery

Drainage area = 10.5 sq. mi.
Sediment delivery ratio = 18%

Annual sediment delivered = 360 af.

= 715,300 tons
= 576,000 cy.

(q) Clearwater Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	3	4.8	14
Tributaries	6	7.0	42
		Total	56

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

56 = 3.15% yearly total = 1,790 af.

(3) Sediment delivery

Drainage area = 27.2 sq. mi.
Sediment delivery ratio = 14%

Annual sediment delivered = 250 af.

= 500,000 tons
= 403,250 cy.

(r) Lower Bean Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac.ft.)
Mainstem	10	3.7	37
Tributaries	20	2.2	44
		Total	81

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

81 = 3.15% yearly total = 2,570 af.

(3) Sediment delivery

Drainage area = 4.2 sq. mi.
Sediment delivery ratio = 22%

Annual sediment delivered = 565 af.

= 1,131,000 tons
= 913,000 cy.

(s) Upper Bean Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
Mainstem	10	1	10
Tributaries	20	1	20
			Total 30

(2) Conversion to yearly total:

Annual precip. average 100"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 3.15% average annual

30 = 3.15% yearly total = 952 af.

(3) Sediment delivery

Drainage area = 1.4 sq. mi.
Sediment delivery ratio = 27%

Annual sediment delivered = 255 af.

= 514,000 tons
= 415,000 cy.

(t) Smith Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
South Smith Creek	40	2.3	92
Smith Creek	10	3.0	30
Smith Creek	130	3.0	390
Tributaries	60	9.0	540
		Total	1,142

(2) Conversion to yearly total:

Annual precip. average 110"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.86% average annual

1,142 = 2.86% yearly total = 40,000 af.

(3) Sediment delivery

Drainage area = 23.55 sq. mi.
Sediment delivery ratio = 15%

Annual sediment delivered = 6,000 af.

= 12,000,000 tons
= 9,678,000 cy.

(u) Muddy Creek Site

(1) Rate of loss May 18 - June 19

Reach	Rate (af./mi.)	Length (mi.)	Erosion (ac./ft.)
lower Bean			81
Clearwater			56
Smith			1,142
Muddy			128
lower Muddy and lower Smith			250
lower Bean			16
lower Clearwater			120
lower Clearwater			70
		Total	1,983

(2) Conversion to yearly total:

Annual precip. average 120"
Precip. May 18 - June 19 Cougar 6E 3.15"
= 2.65% average annual

1,983 = 2.65% yearly total = 74,830 af.

(3) Sediment delivery

Drainage area = 71 sq. mi.
Sediment delivery ratio = 10.5

Annual sediment delivered = 7,900 af.

= 15,800,000 tons
= 12,743,000 cy.

APPENDIX

Physical Properties of Materials

1. Top layer of fine ash material.

a. Depths measured varied from 1 inch to 18 inches in blast zone and classifies as a nonplastic silt (ML) with 57 to 85 percent finer than the number 200 sieve.

b. Low permeability, in the range of 10-4 to 10-5 cm/sec.

c. Specific gravity of 2.62 to 2.67 for most samples is well within the expected range for volcanic soils and rocks.

d. Very severe corrosion will occur in metal structures buried in the material due to the low resistivity (700 to 1,700 ohm-cm) and low pH (6.2 to 6.5) of the material. Metals buried in fine ash are expected to corrode at rates 2 to 3 times higher than for preeruption soils. Metal structures such as gabions and galvanized culverts should be avoided or designed for very severe corrosion.

e. Relative compaction of the material in the field is 77 to 82 percent based on AASHTO T-99 standards with a maximum dry density of 105.5 pounds per cubic foot at an optimum moisture content of 15.9 percent. The material has a moderately high undisturbed dry strength in the field, but will exhibit a very low strength when wet or disturbed.

f. Laboratory strength tests on disturbed samples yielded apparent cohesion and angle of internal friction values of C = 1.1 psi and ° = 2.0. The measured friction angle is much lower than the 10 to 20 degrees expected for the material of this classification, indicating further testing is required to establish more reliable strength data. Tests were performed using back pressure saturation with pore water pressure measurements.

g. No shrinkage of the material due to drying was exhibited in laboratory tests. The only cracks seen in large pan samples developed when the loosely placed dry material was wetted with a water spray. Cracks found in the field are most likely due to settlement and densification of material after it fell, rather than due to shrinkage from drying.

2. Middle layer of pumice.

a. Depths measured varied from 1-1/2 to 6 inches. Pumice is limited to Smith Creek, Bean Creek, and Clearwater drainages and contains 0 to 12 percent passing the number 200 sieve, has a high permeability, and classifies as a poorly graded (SP) and well graded (SW) to silty (SMd) sand.

b. Corrosion to buried metal structures in this material should be moderate to very mild due to its high permeability and coarse texture.

c. Field density of the material was not measured; however, based on tests of the other deposited materials, relative densities of 0 to 25 percent are expected.

d. The material will act like other noncohesive, granular pumice soils found in the area prior to the eruption.

3. <u>Bottom layer of black sand and pyroclastic flow materials.</u>

a. Depths measured varied from 2 to 9 inches and were encountered primarily in the Smith Creek, Bean Creek, and Clearwater Creek drainages. The sand contains 10 to 22 percent passing the number 200 sieve, and classifies as a silty sand (SMd) and poor (SP) to well graded (SW) sand. Flow material in the North and South Toutle Rivers was similar to the black sand materials.

b. Permeability of the samples tested was moderate-to-low, varying from 10-2 to 10-5 centimeters per second.

c. Specific gravities of 2.61 to 2.68 is within the expected range for volcanic soils and rocks.

d. Severe to very severe corrosion will occur in buried metal structures due to the low-to-moderate resistivity (800 to 2,700) and the pH range (5.3 to 6.7).

e. Relative density of the (based on Modified Humphries method) sand in Upper Bean Creek and the surface flow material at the Coldwater Creek Dam was 0 and 25 percent, respectively.

Sands and gravels with relative densities less than 70 percent can liquefy and flow when they fail. Instantaneous liquefication and downslope movement of broad areas of sandy material is expected for the materials tested. The materials will erode rapidly on steep slopes causing undercutting and gully edge collapse leading to local mudflows. The layering of impermeable and permeable layers on steep slopes combined with heavy rains will result in frequent small slides and mudflows where water pressures develop due to slope breaks, waterflow, and layer discontinuities. Slides or mass wasting can also be triggered by seismic shock.

f. Laboratory strength tests on disturbed samples yielded apparent cohesion and internal friction values of C = 0.5 psi and 0 = 5.6° for black sand in upper Clearwater Creek and C = 0 to 0.4 psi and 0 = 7.6° to 5.0° for Coldwater Dam. The measured friction angles are lower than the 25 to 35 degrees anticipated, indicating a need for additional testing to more accurately determine strength values for this material.

The crust in all areas tested wetted readily with and without an agricultural wetting agent. The use of the wetting agent increased the rate of water penetration into the soil. The increased penetration did not appear to justify the cost of the treatment.

SUMMARY OF MATERIALS TESTS FOR
MT. ST. HELENS WATERSHED REHABILITATION

LAB SAMPLE NUMBER	FIELD SAMPLE NUMBER	LOCATION	SAMPLED FROM	DEPTH (in.)	SAMPLE DESCRIPTION	CLASSIFICATION		
						UNIFIED	AASHTO	VISUAL
0192-26-01	13A-1-B	Sec. 3, T9S, R6E NE 1/4 of SW 1/4	Upper Clear-water Drainage	2 3/4 to 6 1/4	Fine sand, black, ash	SM_d	A-2-3(0)	Dark grey silty sand; small amount of pumice
0192-26-02	13A-1-M	Sec. 3, T9S, R6E NE 1/4 of SW 1/4	Upper Clear-water Drainage	1/4 to 2 3/4	Pumice soil, frag-ments to 2" size	SW-SM_d	A-1-b(0)	Predominantly pumice - light grey; material breaks down under compac-tion
0192-26-03	9A-1-T		Green River - 7/8/80 Stop 1	0 to 2 1/2	Volcanic ash, fine; surface layer	ML	A-4(0)	Fine ash and silt; dark grey
0192-26-04	9A-1-B		Green River - 7/8/80 Stop 1	2 1/2 to 3 1/2	Volcanic ash, fine, sandy; black when damp	SM_d	A-2-4(0)	Sand, dark grey, contaminated with fine ash
0192-26-05	13A-1-T	Sec. 3, T9S, R6E NE 1/4 of SW 1/4	Upper Clear-water Drainage	0 to 1/4 crust	Fine grained ash, silt texture	ML	A-4(0)/ A-5(0)	Very fine ash, (silty) Silt with low plasticity

SUMMARY OF MATERIALS TEST (Continued)

LAB SAMPLE NUMBER	PLASTICITY	SIEVE, p 200	HYDROMETER, p 200	RESISTIVITY, chm-cm	pH	PERMEABILITY K, cm/sec	AASHTO, T 100 Sp. Gr.	AASHTO, T 176 SAND EQ.	AASHTO T 19: RODDED DENSITY, pcf	AASHTO T 19: LOOSE DENSITY, pcf	MODIFIED HUMPHRIES DENSITY, pcf	AASHTO T 99: OPT. MOISTURE	AASHTO T 99: MAX. DENSITY, pcf	MOISTURE CONTENT, AS RECEIVED	FIELD DENSITY: DRY, pcf	FIELD DENSITY: WET, pcf	FIELD MOISTURE CONTENT, SHELBY TUBE
0192-26-01	NP	12.7	17.8	700	6.5		2.62	71						6.1%			
						#0192-26-01 (Triaxial Test - C=0.5psi, ϕ=5.6^{o})											
0192-26-02	NP	11.6	18.51				2.44	54				17.2	81.9	2.9%			
0192-26-03	NP	76.1	74.5	700	6.3		2.62	7						7.5%			
0192-26-04	NP	19.4	18.11				2.62	54						4.5%			
0192-26-05	NP	75.6	73.7	700	6.2		2.62	7						0.42%			

SUMMARY OF MATERIALS TESTS FOR
MT. ST. HELENS WATERSHED REHABILITATION

LAB SAMPLE NUMBER	FIELD SAMPLE NUMBER	LOCATION	SAMPLED FROM	DEPTH (in.)	SAMPLE DESCRIPTION	CLASSIFICATION		
						UNIFIED	AASHTO	VISUAL
0193-26-01	3-2-B	Sec. 12, T9S, R4E NW 1/4 of NW 1/4	Debris dam-mouth of Coldwater/ S. Coldwater Cr.	1 1/2 to 6	Gravelly sand layer	$SP\text{-}SM_d$	A-1-b(0)	Pumice; gravel; gravelly, silty sand
0193-26-02	PNW-1-T	Sec. 4, T9N, R4E SW 1/4 of NE 1/4	S. Fork Toutle, just downriver from conflux w/ Disappointment Cr.	0 to 1	Sand	SP	A-3(0)	Silty sand; some pumice
0193-26-03	14A-2-M	Sec. 17, T9N, R6E SE 1/4 of SE 1/4	Bean Cr.	1/4 to 4	Pumice soil - #10 to 1 1/2"	SP	A-1-A(0)	Predominantly pumice, (grav-elly) - light grey
0193-26-04	14A-2-B	Sec. 12, T9N, R6E SE 1/4 of SE 1/4	Bean Cr.	4 to 12	Black sand (ash)	SM_d	A-2-4(0)	Gravelly silty sand
0193-26-05	PNW-1-B	Sec. 4, T9N, R4E SW 1/4 of NE 1/4	S. Fork Toutle, just downstream from conflux w/ Disappointment Cr.	1 to 6	Gravelly sand	SM_d	A-2-4(0)	Dark grey silty sand; gravelly silty sand
0193-26-06	14A-2-T	Sec. 17, T9N, R6E SE 1/4 of SE 1/4	Bean Cr.	0 to 1/4	Top ash	ML	A-4(0)	Dark grey fine ash (silty) Silt with low plasticity
0193-26-07	9B-2-T	Sec. 0, T10N, R6E	Green River	0 to 1 1/2	Fine ash	ML	A-4(0)	Predominantly dark grey fine ash, some pumice
0193-26-08	3-2-T	Sec. 12, T9S, R4E	Debris dam-mouth of Coldwater/ S. Coldwater Cr.	0 to 1 1/2	Fine ash, top layer, weak crust	ML	A-4(0)	Dark grey fine ash (silty)

SUMMARY OF MATERIALS TEST (Continued)

LAB SAMPLE NUMBER	PLASTICITY	SIEVE, p 200	HYDROMETER, p 200	RESISTIVITY, ohm-cm	pH	PERMEABILITY K, cm/sec	AASHTO, T 100 Sp. Gr.	AASHTO, T 175 SAND EQ.	AASHTO T 19 RODDED DENSITY, pcf	AASHTO T 19 LOOSE DENSITY, pcf	MODIFIED HUMPHRIES DENSITY, pcf	AASHTO T 99 OPT. MOISTURE	AASHTO T 99 MAX. DENSITY, pcf	MOISTURE CONTENT, AS RECEIVED	FIELD DENSITY DRY, pcf	FIELD DENSITY WET, pcf	FIELD MOISTURE CONTENT, SHELBY TUBE
0193-26-01	NP	10.2	26.4	850	6.2	1.6×10^{-2}	2.68	42.1	111.4	98.1	119.4	9.3%	126.6	4.3%	103.9	109.7	5.5%
														(25.2% Relative Density)			
0193-26-02	NP	0.1	2.4	2700	6.5	8.1×10^{-3}	2.66	92.5	89.4	81.9	88.4	17.0%	89.3	0.15%			
0193-26-03	NP	0.6	8.15	1700	6.7		2.64	69.7	60.6	53.7	62.5			17.7%			
0193-26-04	NP	15.7	11.2	800	6.3	8.9×10^{-5}	2.60	92.5	101.3	91.2	102.6	14.7%	106.3	12.7%	89.3	103.3	15.6%
						#0193-26-04 (Triaxial Test 1: C=0.0 to 0.4 psi; ϕ=7.6° to 5.0°)									(0% Relative Density)		
0193-26-05	NP	21.9	19.4	2700	5.3	8.0×10^{-5}	2.69	54.0	100.3	83.9	122.2	9.7%	117.2	9.8%			
0193-26-06	NP	72.2	84.0	1700	6.2		2.63	6.0						4.6%			
						#0193-26-06 (Triaxial Test: C=1.1 psi; ϕ=2.0°)											
0193-26-07	NP	77.3	75.9	1200	6.3		2.63	6.0						6.2%	80.9	87.7	8.4%
												15.9% (combined)	105.5	(77% Relative Compaction)			
0193-26-08	NP	79.6	74.58	800	6.5		2.67	6.0						8.6%	86.7	93.9	8.3%
														(82% Relative Compaction)			

SUMMARY OF MATERIALS TESTS FOR
MT. ST. HELENS WATERSHED REHABILITATION

LAB SAMPLE NUMBER	FIELD SAMPLE NUMBER	LOCATION	SAMPLED FROM	DEPTH (in.)	SAMPLE DESCRIPTION	CLASSIFICATION		
						UNIFIED	AASHTO	VISUAL
0210-26-01	3-1	Sec. 23, T8N, R6E SE 1/4 of NW 1/4	Muddy Creek Channel		Dark grey ash, silty, sandy	SM_d	A-2-4(0)	
0210-26-02	3-7-B	Sec. 35, T10N, R5E NW 1/4 of NE	Mt. Margrette	0-15"	Dark grey ash, some pumice (fine silt)	SM_d	A-2-4(0)	
0210-26-03	3-7-A	Sec. 35, T10N, R5E NW 1/4 of NE 1/4	Mt. Margrette	0-15"	Dark grey fine ash	ML	A-4-(0)	
0210-26-04	3-2-A	Sec. 8, T9N, R4E SE of SW	N. Toutle at Jackson Creek	0-8"	Very fine ash, grey	ML	A-4-(0)	
0217-26-01	4-B	Sec. 15, T9N, RSE	Spirit Lake outlet (PBP)	5' gulley	Gravel with bulk grains (no cohesion)	SP-SM_d	A-1-b(0)	
0217-26-02	4-1T	Sec. 15, T9N, RSE	Spirit Lake outlet (PBP)	0-8"	Dark grey fine ask	ML	A-4(0)	
0218-26-01	5-1	Sec. 8, T9N, R6E	Surface stream bank, Upper Bean Creek		Rounded pebbles	SP	A-1-b(0)	No Cohesion

SUMMARY OF MATERIALS TEST (Continued)

LAB SAMPLE NUMBER	PLASTICITY	SIEVE, p 200	HYDROMETER, p 200	RESISTIVITY, ohm-cm	pH	PERMEABILITY K, cm/sec	AASHTO, T 100 Sp. Gr.	AASHTO, T 175 SAND EQ.	AASHTO T 19 RODDED DENSITY, pcf	AASHTO T 19 LOOSE DENSITY, pcf	MODIFIED HUMPHRIES DENSITY, pcf	AASHTO T 99 OPT. MOISTURE	AASHTO T 99 MAX. DENSITY, pcf	MOISTURE CONTENT, AS RECEIVED	FIELD DENSITY DRY, pcf	FIELD DENSITY WET, pcf	FIELD MOISTURE CONTENT, SHELBY TUBE
0210-26-01		23.7	23.4				2.68	39									
0210-26-02		22.3	19.7				2.67	44									
0210-26-03		57.6	41.8				2.68	18							87.6	108.8	24.1
0210-26-04		63.7	65.8				2.54							13.3			
0217-26-01		9.9	9.5				2.7	60									
0217-26-02		61.4	62.3				2.56	9				20.3	92.6				
0218-26-01		1.3	1.7				2.7										

DATE 8-29-80

FROM:

Soil Physics Lab.
Oregon State University
Corvallis, Oregon 97331

TO:

Steve Howes
U.S. Forest Service
Watershed Management
P.O. Box 3623
Portland, Or. 97208

SUBJECT:

(A) Moisture Tensions
(% Moisture - by Weight)

Log No.	Sample Description	Bar 0.1	0.33	0.8	1.0	3.0	5.0	15.0		
26	3-2-T	27.0	13.8	15.3	9.9	7.6	6.2	3.6		
27	9A-1-B	7.6	6.3	4.6	3.9	3.7	3.2	2.1		
28	9A-1-T	27.0	14.6	16.1	11.1	8.1	5.9	3.6		
29	9B-2-T	28.7	14.1	16.1	9.9	7.0	5.3	3.1		
30	13A-1-B	6.7	4.8	4.0	3.0	2.7	1.9	2.0		
31	13A-1-T	25.2	18.3	13.8	9.2	5.9	4.1	2.5		
32	13A-1-M	12.9	11.0	7.9	5.8	5.7	3.5	3.5		
33	14A-2-T	24.5	17.7	13.7	8.4	5.9	4.1	2.4		
34	PNW-1-T	3.1	2.6	2.1	2.0	1.7	1.3	1.4		

Small inconsistencies can be noted on 3 samples (Log # 26, 28, 29) between 0.33 and 0.8 bar tensions. Since the check standard and your other samples gave reasonable results, the runs themselves appear to be good. Discrepancies such as these may be due to variability within your bulk sample.

Mary Kay Amistadi

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Engineering Soils and Materials Testing Laboratory

Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Upper Clearwater drainage
Traffic

Forest Sample No. 13-A-1-B
Location of Sample Sec. 3-T.9-S R-6E
1/4 NE of 1/4 SW Depth 2-3/4 to 6-1/4
Sampled by Steward (RO) 7-8-80

TEST RESULTS

Lab. Sample No. 0192-26-01
Date Tests Completed 7-30-80

Date Sample Received 7-11-80
Date Report Written 8-13-80

AASHO Class A-2-3 (0)
USC Class Smd
Texture Fine sand (dark grey ash)
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 99.7
%Passing No. 10 98.6
%Passing No. 30
%Passing No. 40 69.3
%Passing No. 200 12.7
Specific Gravity 2.62
Hydrometer #200 17.77

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 71
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density 100.9* lb/cu. ft.
Optimum Moisture 16.0 %
Moisture Cont. as Rec. 5.6%
Moisture " " " 6.6%

Remarks. Poorly graded and fine.

pH = 6.5

Resistivity = 700 ohm cm

Triaxial Test: c = 0.5 psi + Ø 5.6°

*AASHTO T-99

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Upper Clearwater drainage
Traffic

Forest Sample No. 13A-1-M
Location of Sample Sec. 3-T.9S R.6E
NE 1/4 of SW 1/4 Depth. 1/4"-2-3/4"
Sampled by Steward (RO) 7-8-80

TEST RESULTS

Lab. Sample No. 0192-26-02
Date Tests Completed

Date Sample Received 7-10-80
Date Report Written 8-13-80

AASHO Class A-1-b (0)
USC Class SW-SMd
Texture
%Passing 1-1/2" 100.0
%Passing 3/4" 98.4
%Passing No. 4 81.2
%Passing No. 10 69.8
%Passing No. 30
%Passing No. 40 31.1
%Passing No. 200 11.6
Specific Gravity 2.44
Hydrometer #200 18.5%

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 54
LA Abrasion % Loss Grading
Durability Index
CBR
*Maximum Density 81.9 lb/cu. ft.
Optimum Moisture 17.2 %
Moisture Cont. as Rec. 2.9%

Remarks:

Pumice Soil, fragments (large amounts of pumice)

*AASHTO T-99

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Forest: Gifford Pinchot
Project: Mt. St. Helens Rehab.
Road No.: Green River Stop 1
Traffic:

Forest Sample No.: 9A-1-T
Location of Sample: Green River Surface Layer
Sampled by: Steward (RO) 7-7-80

TEST RESULTS

Lab. Sample No.: 0192-26-03
Date Tests Completed: 8/6/80

Date Sample Received: 7-16-80
Date Report Written: 8-13-80

AASHO Class: A4(0)
USC Class: ML
Texture: Volcanic Ash Fine (silty)
%Passing 1-1/2": 100.0
%Passing 3/4": 100.0
%Passing No. 4: 100.0
%Passing No. 10: 98.1
%Passing No. 30:
%Passing No. 40: 93.1
%Passing No. 200: 76.1
Specific Gravity: 2.62
Hydrometer #200: 74.5

Liquid Limit: NP
Plastic Limit: NP
Plasticity Index: NP
Sand Equivalent: 7
LA Abrasion % Loss: Grading:
Durability Index:
CBR:
Maximum Density: lb/cu. ft.
Optimum Moisture: %
Moisture Cont. as Rec.: 7.45%

Remarks:

pH = 6.3

Resistivity - 700 ohm cm

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Green River Sand
Traffic

Forest Sample No. 9A-1-B
Location of Sample Green River Stop 1 Depth 2-1/2"-3-1/2"
Sampled by Steward (RO) 7-8-80

TEST RESULTS

Lab. Sample No. 0192-26-04
Date Tests Completed 7/23/80

Date Sample Received 7-9
Date Report Written 8/13/80

AASHO Class A-2-4 (0)
USC Class SMd
Texture Fine ash (silty)
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 99.3
%Passing No. 10 97.1
%Passing No. 30
%Passing No. 40 75.6
%Passing No. 200 19.4
Specific Gravity 2.62
Hydrometer #200 18.11

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 54
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %
Moisture Cont. as Rec. 4.5%

Remarks:

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Upper Clearwater drainage
Traffic

Forest Sample No. 13A-1-T
Location of Sample Sec. 3 T.9S R-6E NE 1/4-SW 1/4, Depth 0-1/4 Crust
Sampled by Steward (RO) 7-8-80

TEST RESULTS

Lab. Sample No. 0192-26-05
Date Tests Completed

Date Sample Received 7/14/80
Date Report Written 8/13/80

AASHO Class A-4(0)/A-5(0)
USC Class ML
Texture Fine grained ash-silt
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 99.6
%Passing No. 10 99.3
%Passing No. 30
%Passing No. 40 98.9
%Passing No. 200 75.6
Specific Gravity 2.62
Hydrometer #200 73.72

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 7
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %
Moisture as Rec. 0.42%

Remarks:

pH = 6.2

Resistivity - 700 ohm cm

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Gravelly sand layer; 100 ft. long
Traffic

Forest Sample No. 3-2-B
Location of Sample Sec. 12 T.-9S R-4E
Debris dam at month of Coldwater
Sampled by Patterson (RO) 7-10-80

TEST RESULTS

Lab. Sample No. 0193-26-01
Date Tests Completed 8/5/80

Date Sample Received 7/10/80
Date Report Written 8-13-80

AASHO Class A-1-b (0)
USC Class SP-SMd
Texture Pumice Gravelly silty sand
%Passing 1-1/2" 89.0
%Passing 3/4" 76.3
%Passing No. 4 60.2
%Passing No. 10 51.7
%Passing No. 30
%Passing No. 40 35.4
%Passing No. 200 10.2
Specific Gravity 2.68
Hydrometer #200 26.39

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 43
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density 126.6* lb/cu. ft.
Optimum Moisture 9.3 %

Remarks:

Moisture as rec. 4.3%

Field density - Shelby Tube 2"x5" taken for field moisture + density

Dry density = 103.94 Lb/cu. ft. @ 5.52% moisture

Wet density = 109.68 Lb/cu. ft.

pH = 6.2

Resistivity = 850 ohm cm

Modified Humphries = 119.4 Lb/cu. ft.

Permeability = 1.6×10^{-2} cm/sec

Relative density = 25.2%

Loose density = 98.08 Lb/cu. ft.

Rodded density = 111.37 Lb/cu. ft.

Triaxial Test C= 0.8 to 1.7 PSC and Ø = 7.5^{0} to 5.5^{0}

*AASHTO T-99

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Gravelly sand layer
Traffic

Forest Sample No. 3-2-B
Location of Sample Sec. 12 T.-9S R-4E
Debris dam at month of Coldwater
Sampled by Steward (RO)

TEST RESULTS

Lab. Sample No. 0193-26-01
Date Tests Completed 8/5/80

Date Sample Received 7/10/80
Date Report Written 8-13-80

AASHO Class A-1-b (0)
USC Class SP-SMd
Texture Pumice Gravelly silty sand
%Passing 1-1/2" 89.0
%Passing 3/4" 76.3
%Passing No. 4 60.2
%Passing No. 10 51.7
%Passing No. 30
%Passing No. 40 35.4
%Passing No. 200 10.2
Specific Gravity 2.68
Hydrometer #200 26.39

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 43
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density 126.6* lb/cu. ft.
Optimum Moisture 9.3 %

Remarks:

Moisture as rec. 4.3%

Field density - Shelby Tube 2"x5" taken for field moisture + density

Dry density = 103.94 Lb/cu. ft. @ 5.52% moisture

Wet density = 109.68 Lb/cu. ft.

pH = 6.2

Resistivity = 850 ohm cm

Modified Humphries = 119.4 Lb/cu. ft.

Permeability = 1.6×10^{-2} cm/sec

Relative density = 25.2%

Loose density = 98.08 Lb/cu. ft.

Rodded density = 111.37 Lb/cu. ft.

Triaxial Test C = 0.8 to 1.7 P5C and Ø = 7.5^{o} to 5.5^{o}.

*AASHTO T-99

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Forest: Gifford Pinchot
Project: Mt. St. Helens Rehab.
Road No.: Sampled from SO.Fork of Toutle R.
Traffic:

Forest Sample No.: PNW-1-T
Location of Sample: Sec. 4-T.-9N R.4E 1/4 SW, 1/4 NE, depth top 1"
Sampled by: Larry Vallard 7-9-80 (PNW)

TEST RESULTS

Lab. Sample No.: 0193-26-02
Date Tests Completed: 8/5/80

Date Sample Received: 7/8/80
Date Report Written: 8/13/80

AASHO Class: A-3(0)
USC Class: SP
Texture: Silty sand, some pumice
%Passing 1-1/2": 100.0
%Passing 3/4": 100.0
%Passing No. 4: 99.9
%Passing No. 10: 99.3
%Passing No. 30:
%Passing No. 40: 64.6
%Passing No. 200: 0.1
Specific Gravity: 2.66
Hydrometer#200: 2.38

Liquid Limit: NP
Plastic Limit: NP
Plasticity Index: NP
Sand Equivalent: 92
LA Abrasion % Loss: Grading:
Durability Index:
CBR:
Maximum Density: 89.3* lb/cu. ft.
Optimum Moisture: 17.0 %
Moisture as Rec.: 0.15

Remarks:

Loose density = 81.91 Lb/cu. ft.

Rodded density = 89.35 Lb/cu. ft.

pH = 6.5

Resistivity - 2700 ohm cm

Permeability = 8.1×10^{-3} cm/sec.

Modified Humphries density = 88.4 Lb/cu. ft.

*AASHTO T-99

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Bean Creek
Traffic

Forest Sample No. 14-A-2-M
Location of Sample Sec. 17-T.9N-R.6E
1/4 SE - 1/4 SE - Depth 1/4" to 4"
Sampled by Steward (RO) 7-10-80

TEST RESULTS

Lab. Sample No. 0193-26-03
Date Tests Completed

Date Sample Received 7-11-80
Date Report Written 8-13-80

AASHO Class A-1-a (0)
USC Class SP
Texture Pumice
%Passing 1-1/2" 98.3
%Passing 3/4" 90.9
%Passing No. 4 56.3
%Passing No. 10 36.4
%Passing No. 30
%Passing No. 40 6.6
%Passing No. 200 0.6
Specific Gravity 2.64
Hydrometer #200 8.15

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 68
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %
Moisture Cont. as Rec. 17.7%

Remarks:

Rodded Density = 60.6 Lb/cu. ft

Loose density = 53.7 Lb/cu. ft.

pH = 6.7

Resistivity - 1700 ohm cm

Humphries density = 62.5 Lb/cu. ft.

Note* - Predominantly pumice (gravelly) (light grey)

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Engineering Soils and Materials Testing Laboratory

Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Sampled from Bean Cr.
Traffic

Forest Sample No. 14-A-2-B
Location of Sample Sec. 12-T.9NR 6E
1/4 SE - 1/4 SE, Depth 4"-12"
Sampled by Steward (RO) 7-10-80

TEST RESULTS

Lab. Sample No. 0193-26-04
Date Tests Completed 8/6/80

Date Sample Received 7-14-80
Date Report Written 8-13-80

AASHO Class A-2-4 (0)
USC Class SMd
Texture Black sand (ash)
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 89.6
%Passing No. 10 78.3
%Passing No. 30
%Passing No. 40 51.0
%Passing No. 200 15.7
Specific Gravity 2.60
Hydrometer #200 11.22

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 93
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density 106.3* lb/cu. ft.
Optimum Moisture 14.7 %
Moisture Cont. as Rec. 12.7%

Remarks:

Modified Humphries - 102.6 Lb/cu. ft.

Field density Shelby Tube 2"x5"

Dry density = 89.31 Lb/cu. ft. - wet density = 103.26 Lb/cu. ft.

pH = 6.3

Resistivity - 800 ohm cm

Triaxial:C = 0.0 psi/0.4 psi

ϕ = 7.6°/5.0°

Permeability - 8.9×10^{-5} cm/sec

Permeability Compaction @ 14.25% moisture @ 104.60 Lb/cu. ft.

Loose Density - 91.24 Lb/cu. ft.

Rodded Density - 101.25 Lb/cu. ft.

Relative Density = 0%

AASHTO T-99

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. So. Fork of Touttle
Traffic

Forest Sample No. PNW-1-B
Location of Sample Sec. 4-T-9N-R4E SW 1/4 NE 1/4
Sampled by Vollard (PNW) 7-9-80

TEST RESULTS

Lab. Sample No. 0193-26-05
Date Tests Completed 7/23/80

Date Sample Received 7/21/80
Date Report Written 8/13/80

AASHO Class A-2-4(0)
USC Class SMd
Texture Dark Grey Silty Sand (Gravelly)
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 99.6
%Passing No. 10 90.5
%Passing No. 30 70.0
%Passing No. 40 60.7
%Passing No. 200 21.9
Specific Gravity 2.69
Hydrometer #200 19.43

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 54
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density 117.2* lb/cu. ft.
Optimum Moisture 9.7 %
Moisture Cont. as Rec. 9.8%

Remarks:

Rodded Density = 100.3 Lb/cu. ft.

Loose Density = 83.9 Lb/cu. ft.

Modified Humpries = 122.2 Lbs/cu. ft.

pH = 5.3

Resistivity = 2700 ohm cm

Permeability = 8.0×10^{-5} cm/sec.

Dry Density = Compacted @ 9.83 moisture @ 118.4 Lb/cu. ft.

*AASHTO T-99

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No. Bean Creek - Top ash
Traffic

Forest Sample No. 14-A-2-T
Location of Sample Sec. 17-T.9N R6E
1/4 SE - 1/4 SE Depth 0-1/4"
Sampled by Steward (RO) 7/10/80

TEST RESULTS

Lab. Sample No. 0193-26-06
Date Tests Completed 7/23/80

Date Sample Received 7/11/80
Date Report Written 8/13/80

AASHO Class A-4 (0)
USC Class ML
Texture Dark Grey Fine Ash (silty)
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 98.5
%Passing No. 10 98.3
%Passing No. 30 98.0
%Passing No. 40 97.9
%Passing No. 200 72.2
Specific Gravity 2.63
Hydrometer #200 84.04

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 6
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %
Moisture Cont. as Rec. 4.6%

Remarks:

pH = 6.2

Resistivity = 1700 ohm cm

Triaxial Test : C = 1.1 P5C + Ø = 2.0°.

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Forest: Gifford Pinchot
Project: Mt. St. Helens Rehab.
Road No.: Green River
Traffic:

Forest Sample No.: 9B-2-T
Location of Sample: T.10n R-6E
Top 1-1/2" (0-1-1/2")
Sampled by: Steward (RO) 7/10/80

TEST RESULTS

Lab. Sample No.: 0193-26-07
Date Tests Completed: 8/13/80

Date Sample Received: 7/11/80
Date Report Written: 8/13/80

AASHO Class: A-4 (0)
USC Class: ML
Texture: Fine Ash
%Passing 1-1/2": 100.0
%Passing 3/4": 100.0
%Passing No. 4: 99.8
%Passing No. 10: 99.5
%Passing No. 30: 95.5
%Passing No. 40: 93.9
%Passing No. 200: 77.3
Specific Gravity: 2.64
Hydrometer #200: 75.92

Liquid Limit: NP
Plastic Limit: NP
Plasticity Index: NP
Sand Equivalent: 6
LA Abrasion % Loss: ____ Grading: ____
Durability Index:
CBR:
Maximum Density: ____ lb/cu. ft.
Optimum Moisture: ____ %
Moisture Cont. as Rec.: 6.2%

Remarks:

Field Density 2"x5" Shelby Tube

Dry Density = 80.86 Lb/cu. ft. @ 8.44 % moisture

Wet Density = 87.68 Lb/cu. ft.

pH = 6.3

Resistivity = 1200 ohm cm

* Note: predominantly dark grey fine ash, some pumice

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 3-2-T
Location of Sample Sec. 12 - T.-9S-R4E
1/4 NW-1/4 NW Depth 0-1-1/2"
Sampled by Steward (RO) 7/10/80

TEST RESULTS

Lab. Sample No. 0193-26-08
Date Tests Completed 7/23/80

Date Sample Received 7/11/80
Date Report Written 8/13/80

AASHO Class A-4-(0)
USC Class ML
Texture Dark Grey fine ash (silty)
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 99.6
%Passing No. 10 99.0
%Passing No. 30 96.8
%Passing No. 40 95.8
%Passing No. 200 79.6
Specific Gravity 2.67
Hydrometer #200 74.6

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 6
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %
Moisture Cont. as Rec. 8.6%

Remarks:

Field Density = 2" IDx5" Shelby Tube

Dry Density = 86.69 Lb/cu. ft. @ 8.3% moisture

Wet Density = 93.89 Lb/cu. ft.

pH - 6.5

Resistivity = 800 ohm cm

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 3-1
Location of Sample Sec. 23-T-8N R-6E SE 1/4 of NW 1/4; Muddy Creek Channel
Sampled by Steward (RO) 7-24-80

TEST RESULTS

Lab. Sample No. 0210-26-01
Date Tests Completed

Date Sample Received 7-25-80
Date Report Written 8-11-80

AASHO Class A-2-4 (0)
USC Class SMd
Texture
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 96.1
%Passing No. 10 86.5
%Passing No. 30 66.1
%Passing No. 40 58.5
%Passing No. 200 23.7
Specific Gravity 2.68
Hydrometer pass. 200 23.4

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 39
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %

Remarks:

Dark gray ash silty sandy

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 3-7-B
Location of Sample Sec. 35 T-ION R-5E
NW 1/4 of NE Depth 0-15". Mt. Margrette
Sampled by Steward (RO) 7-24-80

TEST RESULTS

Lab. Sample No. 0-210-26-02
Date Tests Completed

Date Sample Received 7-25-80
Date Report Written 8-11-80

AASHO Class A-2-4 (0)
USC Class SMd
Texture
%Passing 1-1/2" 100.0
%Passing 3/4" 98.4
%Passing No. 4 87.9
%Passing No. 10 79.5
%Passing No. 30 63.2
%Passing No. 40 57.1
%Passing No. 200 22.3
Specific Gravity 2.67
Hydrometer #200 19.7

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 44
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %

Remarks: Dark Gray Ash - some pumice (fine silt)

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 3-7-A
Location of Sample Sec. 35-T-ION R-5 E
NW 1/4 NE 1/4 Depth Top 15", Mt. Margrette
Sampled by Steward (RO) 7-24-80

TEST RESULTS

Lab. Sample No. 0210-26-03
Date Tests Completed

Date Sample Received 7-25-80
Date Report Written 8-11-80

AASHO Class A-4 (0)
USC Class ML
Texture
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 98.6
%Passing No. 10 96.0
%Passing No. 30 86.4
%Passing No. 40 81.6
%Passing No. 200 57.6
Specific Gravity 2.68
Hydrometer #200 41.8

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 18
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %

Remarks; Dark Gray Fine Ash

Moisture contents as rec. Bag #1-12.53%, Bag #2-16.0%, Bag #3-14.52%

Shrinkage Test - No signs of shrinkage cracks appearing from top of sample

see pictures-

γ_d = 87.64 PCF

γ_w = 108.77 PCF

w/c = 24.11%

Soil in shrinkage pan after wetting;

Dry unit weight = 87.6 16/ft^3

Wet unit weight = 108.8 16/ft^3

Water content = 24.1%

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Forest: Gifford Pinchot	Forest Sample No. 3-2-A
Project: Mt. St. Helens Rehab.	Location of Sample: Sec. 8-T-9N R-4E SE of SW Depth 0-8"; N. Toutle @ Jackson Cr
Road No.	Sampled by: Steward (RO) 7-24-80
Traffic	

TEST RESULTS

Lab. Sample No. 0-210-26-04	Date Sample Received 7/25/80
Date Tests Completed	Date Report Written 8/11/80

AASHO Class	A-4 (0)	Liquid Limit	NP
USC Class	ML	Plastic Limit	NP
Texture		Plasticity Index	NP
%Passing 1-1/2"	100.0	Sand Equivalent	
%Passing 3/4"	100.0	LA Abrasion % Loss	Grading
%Passing No. 4	99.5	Durability Index	
%Passing No. 10	98.3	CBR	
%Passing No. 30	94.4	Maximum Density	lb/cu. ft.
%Passing No. 40	92.2	Optimum Moisture	As rec. 13.3 %
%Passing No. 200	63.7		
Specific Gravity	2.54		
Hydrometer #200	65.8		

Remarks:

Shrinkage test - Some shrinkage cracks seem to occur during wetting, but hardly noticeable. Shrinkage test was run on materials - #40 and #100. No cracks noticeable - when dried see pictures. Cracks from wetting were noticeable when specimen was removed from container. (Very fine ash) (gray)

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 4-B
Location of Sample Sec.15-T9NR-5E, 5 ft. depth (gully). Spirit L. outlet (PBP)
Sampled by Steward (RO) 8-3-80

TEST RESULTS

Lab. Sample No. 0217-26-01
Date Tests Completed

Date Sample Received 8-4-80
Date Report Written 8-11-80

AASHO Class A-1-b(0)
USC Class SP-SMd
Texture
%Passing 1-1/2" 90.7
%Passing 3/4" 78.9
%Passing No. 4 60.2
%Passing No. 10 50.5
%Passing No. 30 33.4
%Passing No. 40 28.4
%Passing No. 200 9.9
Specific Gravity 2.70

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 60
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %

Remarks· Gravel - Rounded or waterworn pebbles or bulk grains. No cohesion.

Coarse Grained (Granular) large amounts of pumice retained sizes 1-1/2" thru - #4

Apparent specific gravity (coarse) 2.28

Hydrometer passing No.200 9.5%

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 4-1T
Location of Sample Sec. 15-T.9N R-5E
Depth 0-8". Spirit L. outlet (PBP)
Sampled by Steward (RO) 8-3-80

TEST RESULTS

Lab. Sample No. 0217-26-02
Date Tests Completed

Date Sample Received 8-4-80
Date Report Written 8-11-80

AASHO Class A-4 (0)
USC Class ML
Texture
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 98.4
%Passing No. 10 96.8
%Passing No. 30 92.9
%Passing No. 40 90.8
%Passing No. 200 61.4
Specific Gravity 2.56
Hydrometer #200 62.3

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent 9
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density 92.6 lb/cu. ft.
Optimum Moisture 20.3 %

Remarks: Dark Grey Fine Ash

Stability good when dry, Frost action bad - Bearing value poor to fair.

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Forest Gifford Pinchot
Project Mt. St. Helens Rehab.
Road No.
Traffic

Forest Sample No. 5-1
Location of Sample Sec. 8 T.9N R-6E
Surface Stream Bank, Upper Bean Cr.
Sampled by Steward (RO) 8-4-80

TEST RESULTS

Lab. Sample No. 0218-26-01
Date Tests Completed

Date Sample Received 8-5-80
Date Report Written 8-11-80

AASHO Class A-1-b (0)
USC Class SP
Texture
%Passing 1-1/2" 100.0
%Passing 3/4" 100.0
%Passing No. 4 83.5
%Passing No. 10 69.7
%Passing No. 30 43.4
%Passing No. 40 34.2
%Passing No. 200 1.3
Specific Gravity 2.70
Hydrometer #200 1.7

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
Sand Equivalent
LA Abrasion % Loss Grading
Durability Index
CBR
Maximum Density lb/cu. ft.
Optimum Moisture %

Remarks: Rounded or waterworn pebbles or bulk rock grains. No cohesion (very clean)

APPENDIX

Analysis of new impoundments along North Fork Toutle River
Pyroclastic Flow
by
John Mohney and Maureen Peters

1. Stability Analysis.

A preliminary slope stability analysis of the dams on Castle Creek and Coldwater Creek were performed using charts based on Janbu's method 1/. Sections through the dams were developed from preliminary 80 foot contour interval mapping provided by the US Geological Survey. The stability calculation results are approximate indications of stability only. The large scale of the mapping and the lack of validated information regarding materials properties within the embankments prevents making more reliable stability calculations.

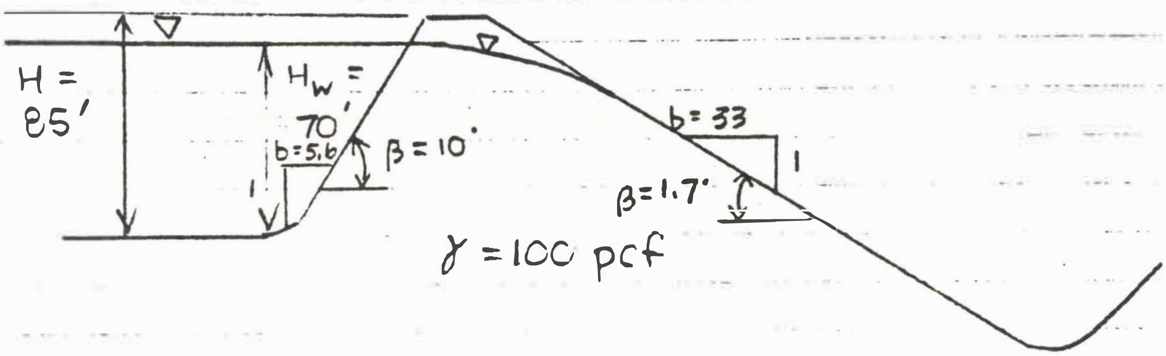
Relative density in the top 6 inches of the Coldwater Creek Dam, measured at 25.2%, is very low. The sample texture is very similar to the airborne sand deposits in Bean and Clearwater Creeks which yielded angles of internal friction of 5.6 to 7 degrees. The preliminary analysis indicates the slopes on these dams (Coldwater Creek and Castle Creek) are marginally stable with these low internal friction angle materials and will become less stable as the impoundments fill with water. An angle of internal friction of 25 to 35 degrees, which appears more reasonable than values measured, based on the observed material in vertical sections and experience, indicates highly stable slopes for static conditions (strength basis). More detailed field mapping, exploration, sampling, testing, and analysis needs to be performed to better evaluate stability of these dams. Stability of the dams needs to be evaluated for static and dynamic loading conditions.

2. Size outlet channel for impoundments (Coldwater Creek, South Coldwater Creek, and Castle Creek)

A preliminary analysis was performed to determine the size of channel outlet required to prevent further downcutting utilizing channel armoring by the larger material in the pyroclastic flow. The channel could be excavated and fine material removed using a hydraulic cannon and small earthmoving equipment. Visually, the pyroclastic flow at Coldwater Creek contains 20% plus 24 inch, 20% 6 to 24 inch, and 60% less than 6 inch, in diameter.

1/ "An Engineering Manual For Slope Stability Studies"; Duncan, J.M. and Bachigmani, A.L.; Dept. of Civil Engineering, Univ. of Calif., March, 1975.

CASTLE CR. DAM STABILITY ANALYSIS RESULTS



UPSTREAM SLOPE

JANBU'S METHOD

Ø	F
5°	0.49
20°	2.0
30°	3.2

(FROM CHART 9)

DOWNSTREAM SLOPE:

INFINITE SLOPE

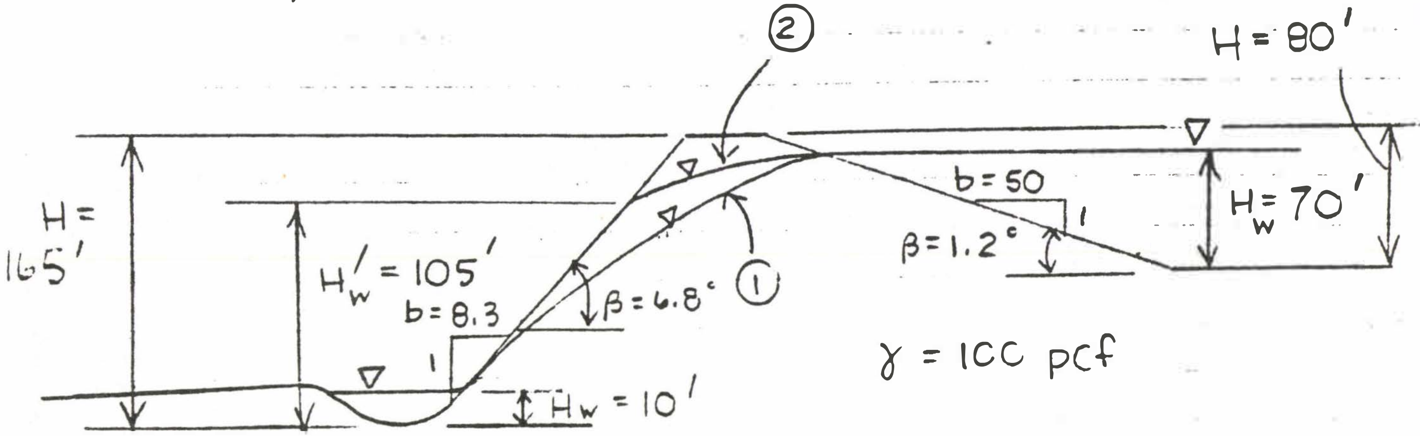
Ø	F
5°	1.0
20°	4.2
30°	6.7

(FROM CHART 10)

1

MKP

COLDWATER CR. DAM STABILITY ANALYSIS RESULTS



UPSTREAM SLOPE

JANBU'S METHOD

ϕ	F
5°	4.4 (FROM CHART 9)
20°	18
30°	29

COLDWATER CR. DAM STABILITY ANALYSIS RESULTS

DOWNSTREAM SLOPE:

JANBU'S METHOD

1

Ø	F
5°	0.73
20°	3.0
30°	4.8

2

Ø	F
5°	0.45
20°	1.9
30°	3.0

FROM CHART 9

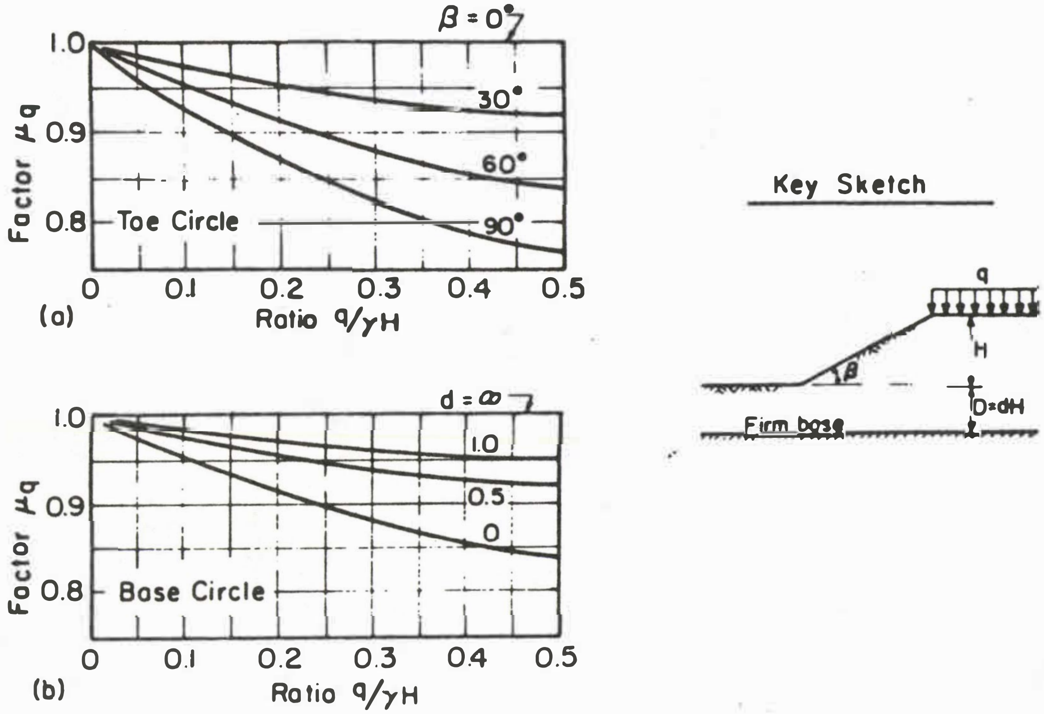
INFINITE SLOPE

1 2

Ø	F
5°	0.26
20°	1.1
30°	1.7

FROM CHART 10

REDUCTION FACTORS FOR SURCHARGE



REDUCTION FACTORS FOR SUBMERGENCE (μ_w) AND SEEPAGE (μ'_w)

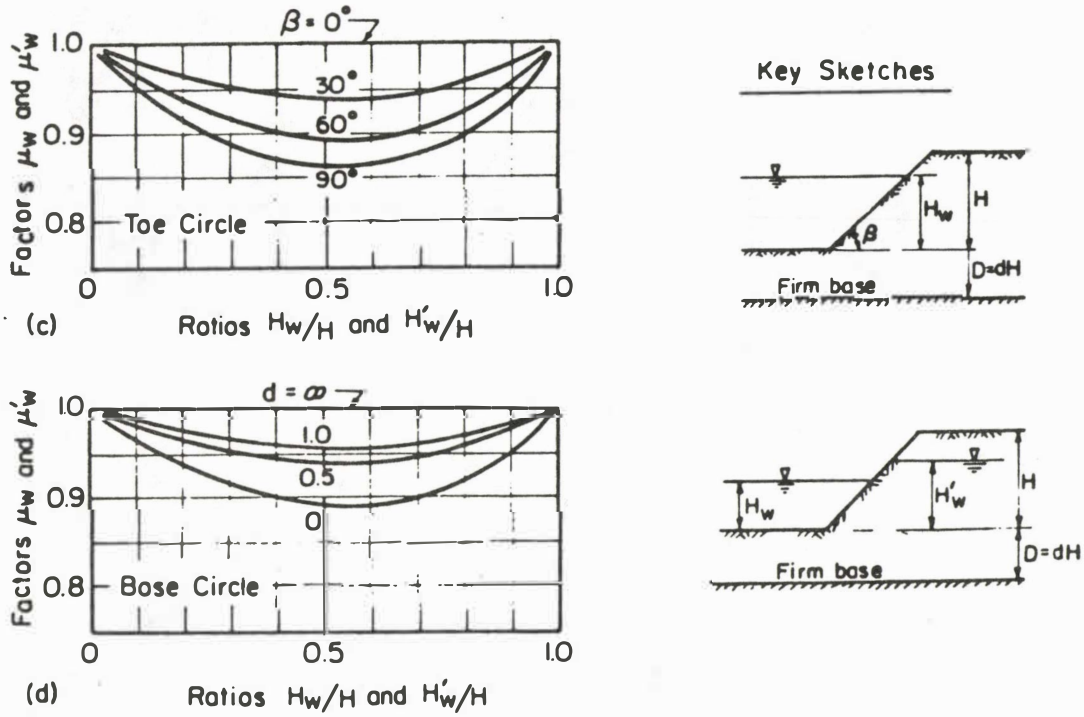
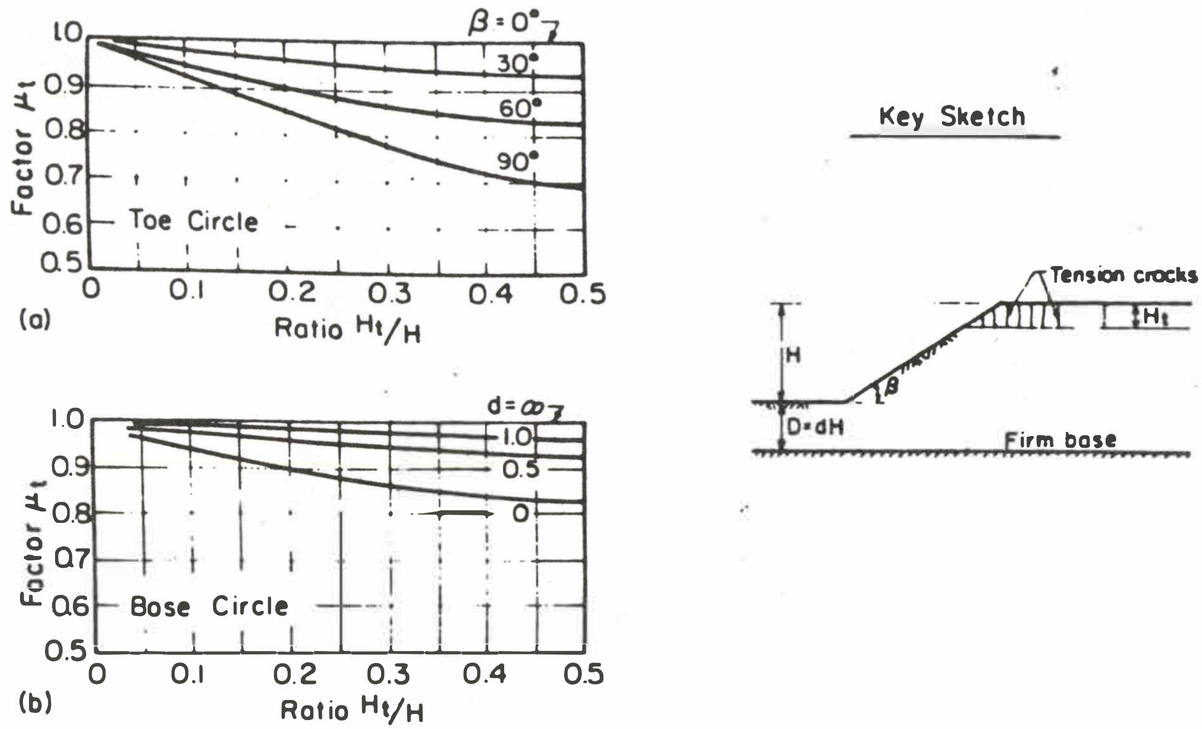


Fig. 7 REDUCTION FACTORS FOR SLOPE STABILITY CHARTS FOR $\phi = 0$ AND $\phi > 0$ SOILS. (after Janbu, 1968)

REDUCTION FACTOR FOR TENSION CRACK
No Hydrostatic Pressure in Crack



REDUCTION FACTOR FOR TENSION CRACK
Full Hydrostatic Pressure in Crack

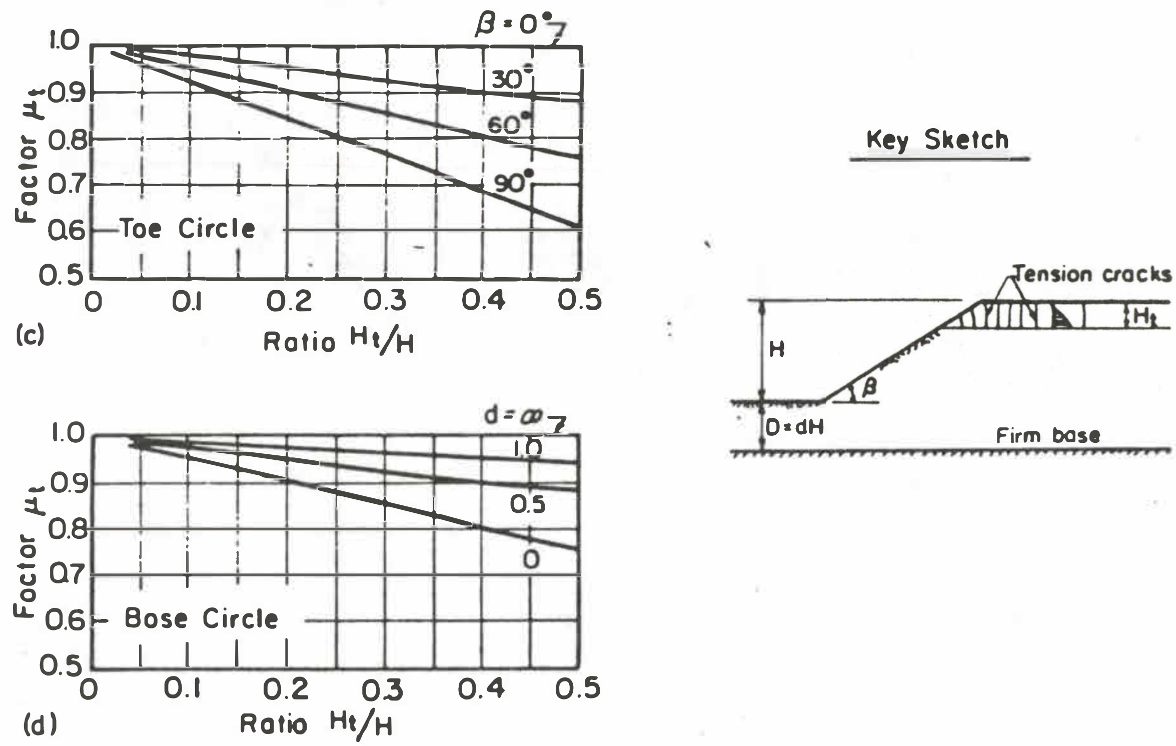
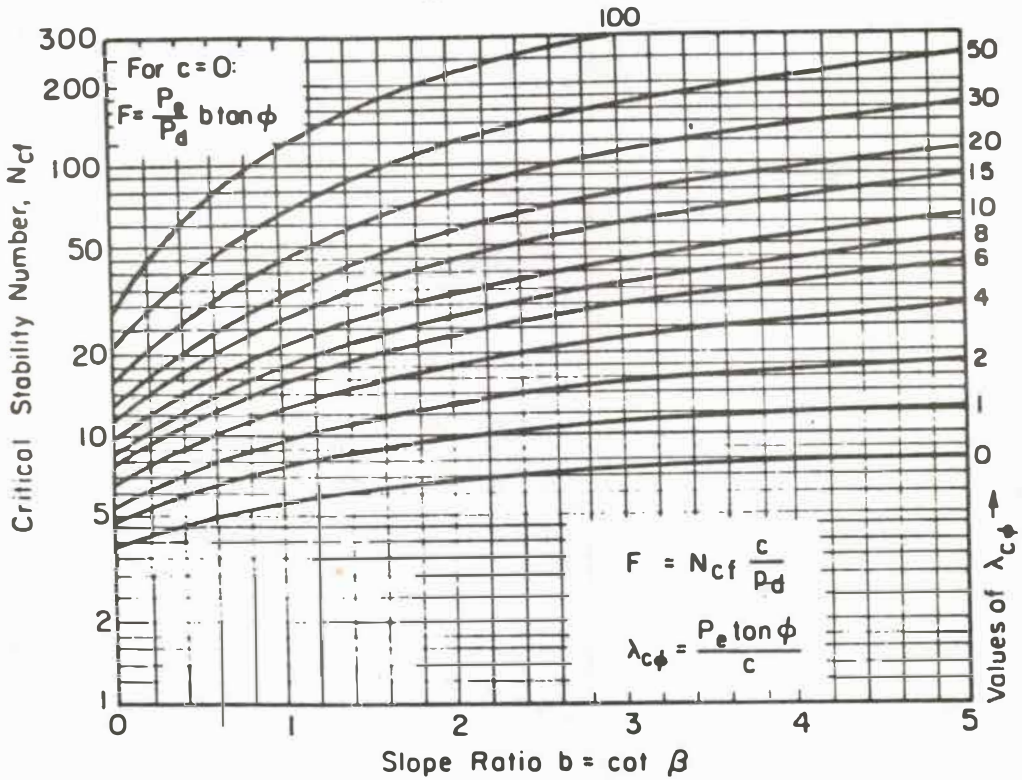
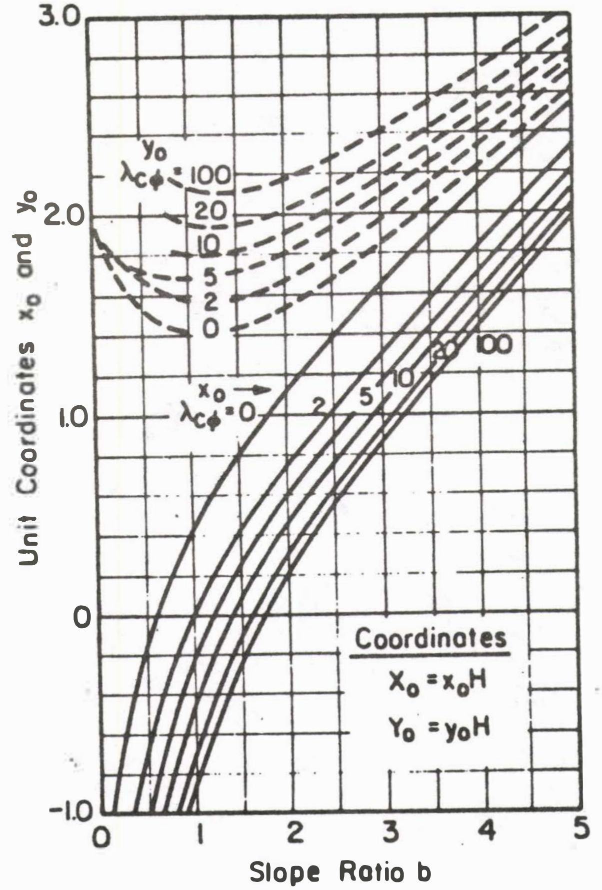
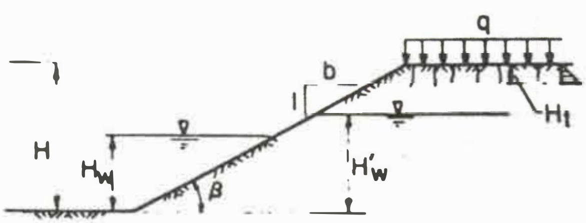


Fig. 8 REDUCTION FACTORS FOR SLOPE STABILITY CHARTS FOR $\phi = 0$ AND $\phi > 0$ SOILS. (after Janbu, 1968)





CENTER COORDINATES FOR CRITICAL CIRCLE



$$P_d = \frac{\gamma H + q - \gamma_w H_w}{\mu_q \mu_w \mu_t}$$

$$P_e = \frac{\gamma H + q - \gamma_w H'_w}{\mu_q \mu'_w}$$

(In formula for P_e take $q = 0$, $\mu_q = 1$ for unconsolidated condition)

Fig. 9 SLOPE STABILITY CHARTS FOR $\phi > 0$ SOILS. (after Janbu, 1968)

γ = total unit weight of soil

γ_w = unit weight of water

C' = cohesion intercept
ϕ' = friction angle } Effective Stress

r_u = pore pressure ratio = $\frac{u}{\gamma H}$

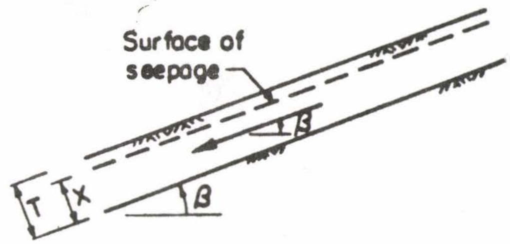
u = pore pressure at depth H

Steps:

① Determine r_u from measured pore pressures or formulas at right

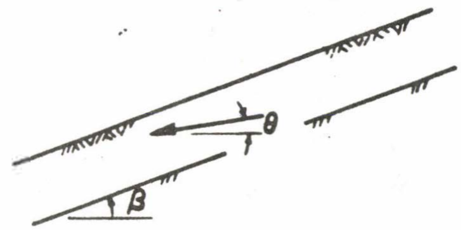
② Determine A and B from charts below

③ Calculate $F = A \frac{\tan\phi'}{\tan\beta} + B \frac{C'}{\gamma H}$



Seepage parallel to slope

$$r_u = \frac{X}{T} \frac{\gamma_w}{\gamma} \cos^2\beta$$



Seepage emerging from slope

$$r_u = \frac{\gamma_w}{\gamma} \frac{1}{1 + \tan\beta \tan\theta}$$

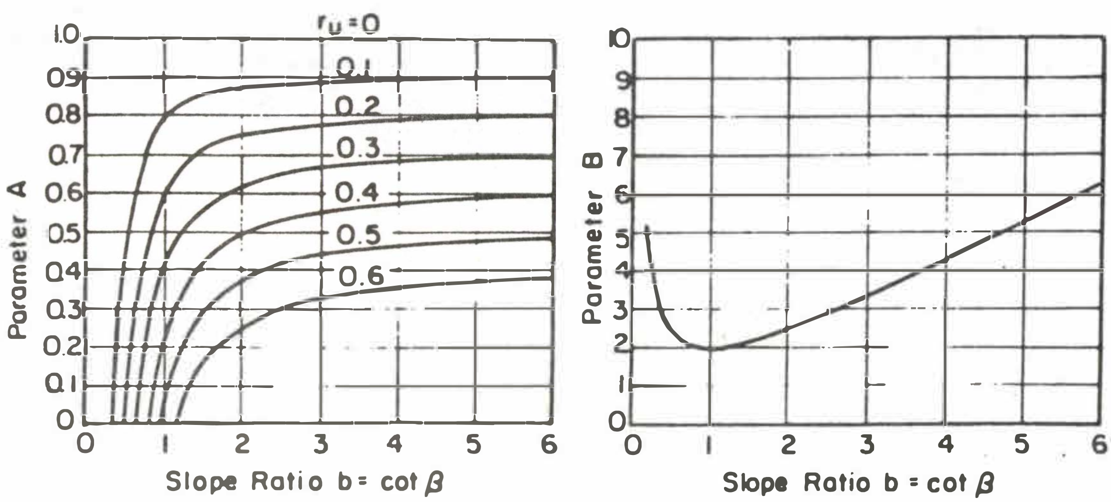


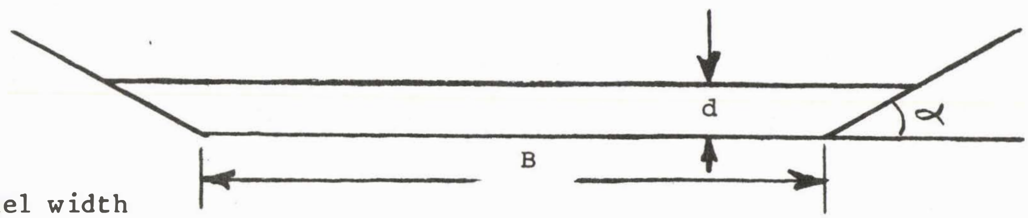
Fig. 10 STABILITY CHARTS FOR INFINITE SLOPES.

The channel sizing was based on the following:

Velocity using Mannings eq:

$$v= \frac{1.486}{n} r \frac{2}{3}$$

n= 0.045
s= Slope (3%, 1.5%)
r= Hydraulic Radius
 = a/p
a= Area
p= Wetted Permitted



B= Channel width
d= Channel depth
 = Side Slope = 3:1

<u>Note</u>: Rock size shown is for critical rock. Two-thirds of rock should be larger. Rock sizes were determined using the Chart D. 2/

2/ "Bank Shore Protection in California Highway Practice," state of California, Department of Transportation.

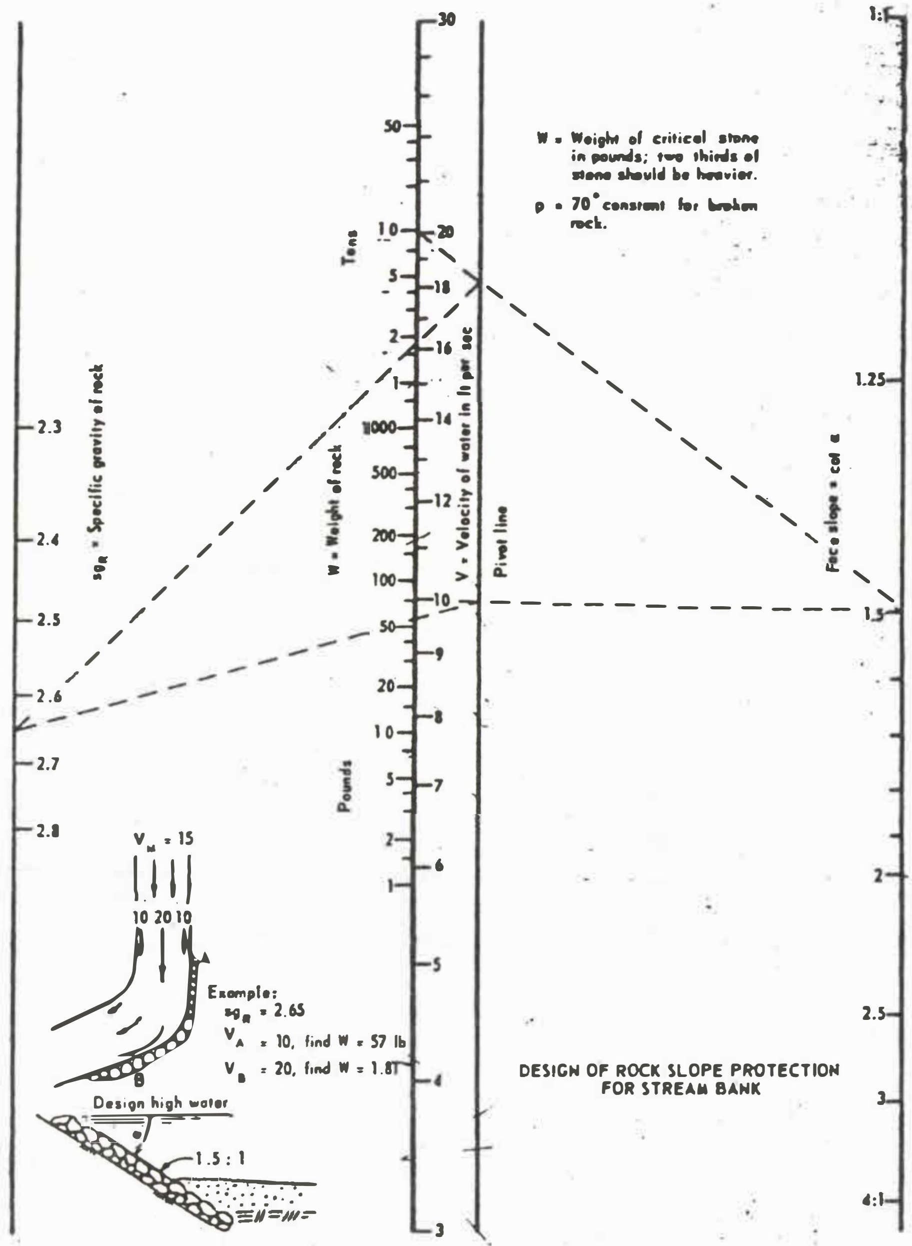


CHART D. Nomograph for design of stream-bank rock slope protection.

Preliminary Channel Sizing

Location	Depth Ft.	Slope %	Width Ft.	v,FPS	Rock Size Dia. In.	Rock Size Wt., Lbs.
Castle Creek	6.0	3.0	20	15.0	17.0	250
	5.7	3.0	30	14.0	15.0	175
(Q= 3500 cfs)	4.5	3.0	40	13.7	14.4	150
	3.8	3.0	60	12.5	12.1	90
	3.4	3.0	80	11.7	10.6	60
	2.9	3.0	100	11.0	9.7	45
		1.5	30	10.9	9.1	38
		1.5	40	10.5	8.6	32
		1.5	80	10.3	8.2	27
S. Coldwater	3.2	3.0	20	13.5	14.0	145
	3.1	3.0	30	12.0	11.5	75
(Q= 2000 cfs)	3.1	3.0	40	11.2	9.8	46
	2.7	3.0	60	10.3	8.5	27
	2.7	3.0	80	9.5	7.0	17
	2.2	3.0	100	8.9	6.3	12
		1.5	30	9.3	6.7	15
		1.5	40	8.9	6.3	12
		1.5	80	7.8	4.7	5
Coldwater	6.8	3.0	20	15.6	19.5	320
	6.2	3.0	30	14.8	17.0	250
(Q= 4230 cfs)	5.5	3.0	40	14.7	16.8	240
	4.5	3.0	60	13.1	13.9	135
	3.8	3.0	80	12.6	12.6	100
	3.4	3.0	100	11.8	10.6	60
		1.5	30	11.5	10.1	52
		1.5	40	11.1	9.7	45
		1.5	80	10.7	8.9	35

3. Capacities and seepage quantities of new impoundments and dams

Capacities and seepage quantities for these impoundments were determined to aid in understanding the magnitude of the situation with these new structures.

The results have been used indirectly in developing conclusions and recommendations in the body of the report.

Reservoir Capacity and Annual Inflow

	Capacity	Annual Inflow
Coldwater Creek	133,000 acre-feet	64,400 acre-feet
South Coldwater Creek	38,000 acre-feet	" "
	171,000 acre-feet	64,000 acre-feet
Castle Creek Marsh (Elevation 2560)	22,600 acre-feet	14,900 acre-feet

Seepage Quantities

Coldwater dam(s)	1,040 acre-feet /year
Castle Creek	500 acre-feet /year

These seepage quantities are based on a permeability of 10^{-4} cm/sec.

Debris (Dam) Deposits; volume and water storage capacity.

	Dam Volume (acre-feet)	Volume of Internal Water Storage to Saturate (acre-feet)
Spirit Lake	1,185,000	142,100
S. Coldwater Creek*	59,000	7,066
Coldwater Creek*	206,100	24,800
Castle Creek Marsh	7,759	932
Sub Total	1.46×10^6	175,000
North Fork Toutle River	1.10×10^6	132,000
Total	2.56×10^6	307,000

* Assumed filled with debris to elevation 2,560.

Dam volumes were based on a comparison between old and new elevations with limits of dams selected visually. Internal water storage capacity was based on a porosity of 18% and 33% saturation (volume basis).

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
GIFFORD PINCHOT NATIONAL FOREST
500 West 12th Street
Vancouver, Washington 98660

REPLY TO: 7170 Materials Engineering

August 6, 1980

SUBJECT: Tephra Removal

TO: Ed Gililland, Operations Engineer

Introduction

On July 30, 1980 Jim Brazil, Zone I Geotechnical Representative and myself observed tephra removal operations on roads 125 and 112. The purpose was to determine if any mass stability problems would result if tephra deposits on the road were sidecasted. For this report mass stability will be defined as a hillside failure that would remove significant amounts of pre-existing soil located under recent tephra deposits.

Recommendations:

When the downhill slope is greater than 55% with no benches within 50 vertical feet below road, the following is recommended:

1. End haul and dispose of material in waste area with 30% or flatter existing slopes.

2. Deposit material down slope. When dry, the ash and pumice tend to slide down the slopes to flatter slopes or deposit as a thin layer. Two methods can be used to accomplish this:

    a. Sidecase and go back with front end loader or grade-all to push any material down slope that gets deposited near road level, and

    b. Windrow and then dump grade-all or backhoe buckets of material out on slope.

Attached are cross sections of conditions to avoid and an allowable sidecase contition.

Findings
At the 125 and 112 junction the tephra consisted of about 1 inch of fine ash over about 2-1/2 inches of uniform pumice (about 3/8 inch in diameter) over about 1/2 inch of medium sand size. There were scattered sub-angular pumice sizes to about 2 inches in diameter. On the cut slopes the pumice depth was greater at the base than the top of the slope due to sliding down slope before ash layer confined it. The fine ash on the surface exhibits some cohesion in place, but is non plastic after remolding. Much of this layer will probably break up with heavy rain and snow and slide down slopes next winter, especially on steep side slopes. Once the ash layer is disturbed the pumice will also move down the slopes. The depth of tephra deposits reduces, gradually driving northward toward Randle to a depth of less than 1 inch and consists mostly of fine ash.

On road 125 no possible mass stability problems were observed, but either the sideslopes were relatively flat or natural benches were within 50 feet below road.

On road 112 there were a number of potential mass stability problems due to sidecasted tephra. There were berms on outside shoulder, filled benches, and oversteepened shoulders. This coupled with the many sidecast failures that were created when the road was built, makes this road a high potential for mass stability failures. The sidecast material was loose and can easily be pushed down slope and the material tends to slide a long distance before stopping. Therefore, it was concluded that this material could be pushed down slope with grade-all or front end loader to solve problem.

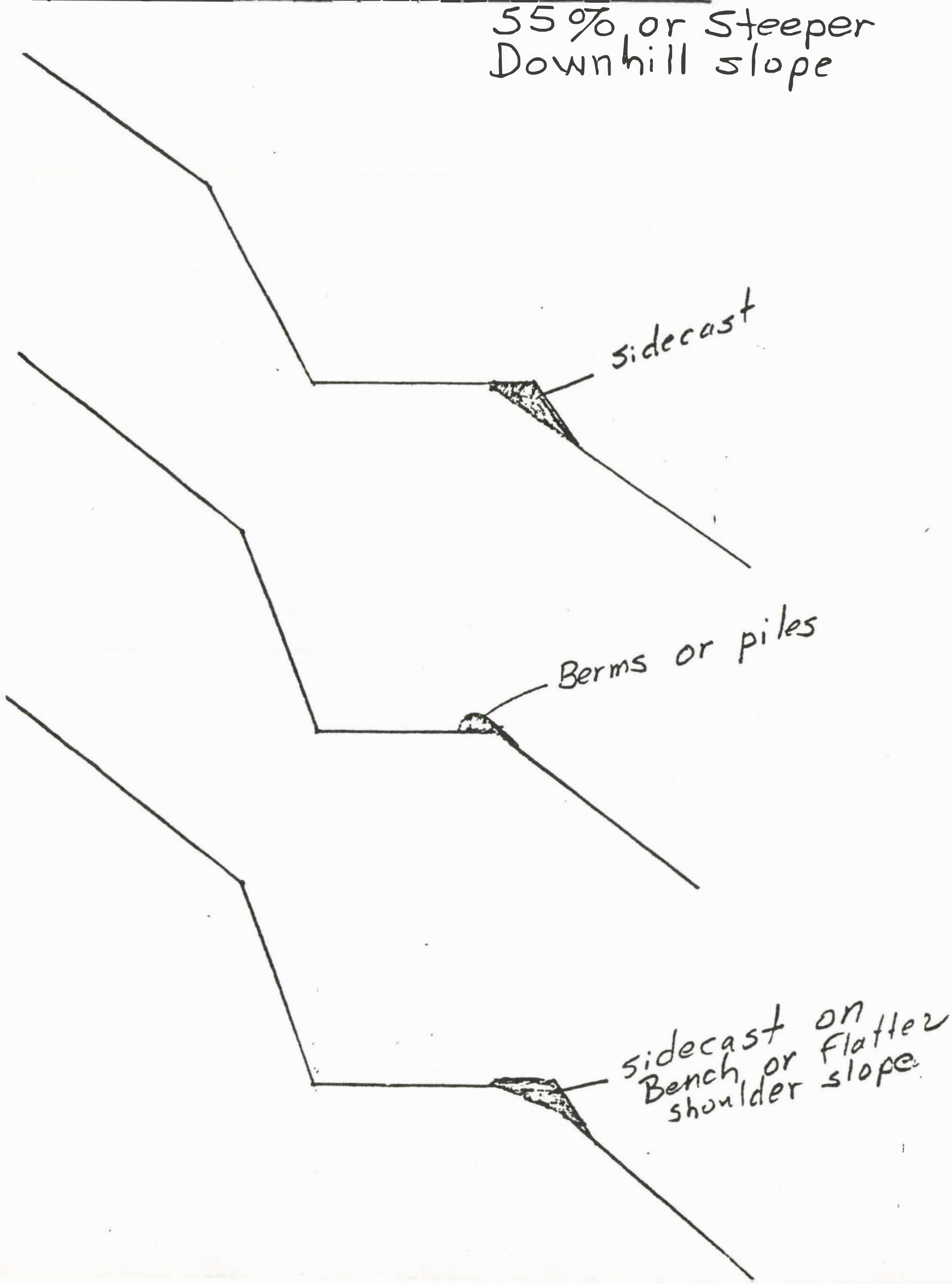
William O. Powell

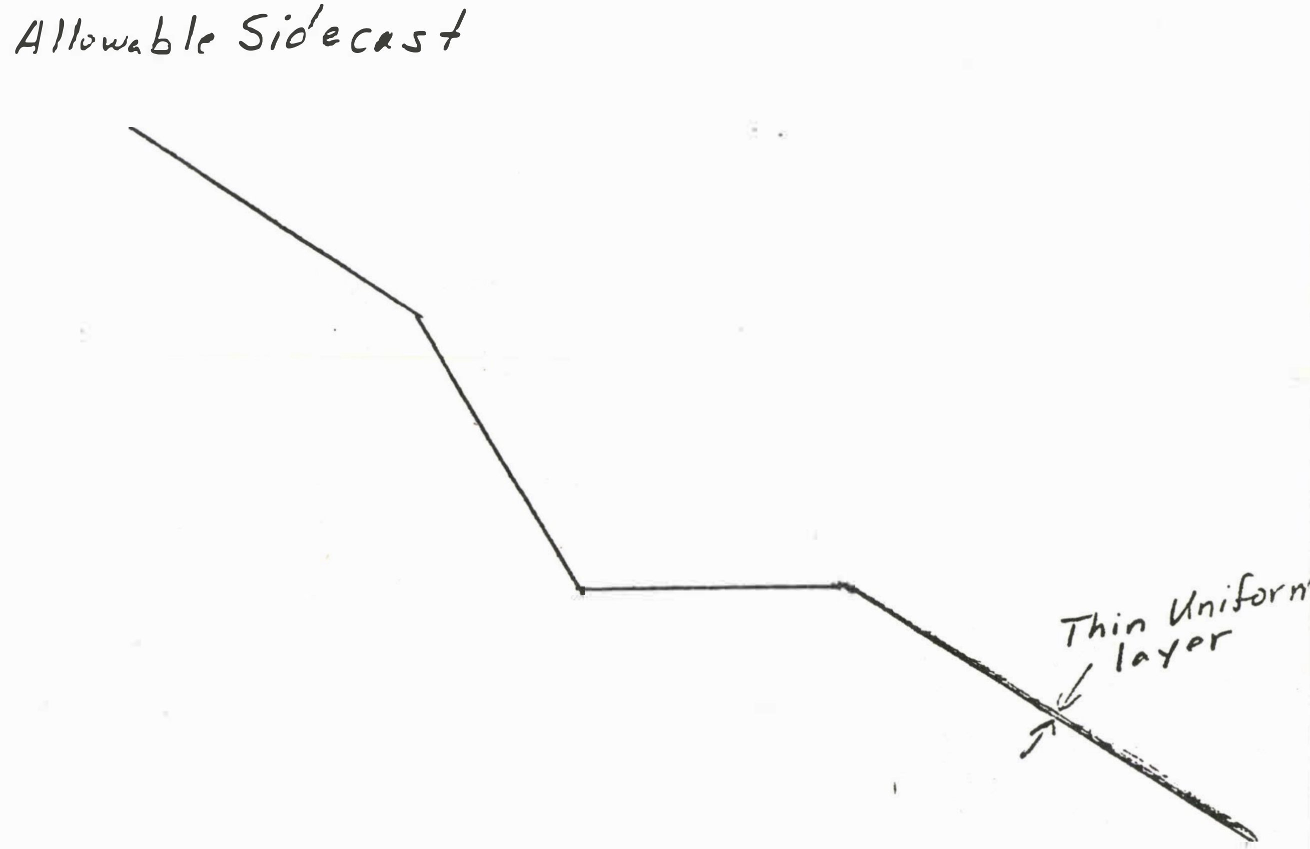
WILLIAM O. POWELL
Geotechnical Engineer

Enclosure

cc: Harold Coates, Randle R.D.
John Steward, R.O. Engineering
Jim Brazil, Zone I Engineering

Sidecast Situations To Avoid.




Allowable Sidecast
Thin Uniform
layer

PACIFIC POWER & LIGHT COMPANY
920 S.W. SIXTH AVENUE · PORTLAND, OREGON 97204 · (503) 243-1122

Portland, Oregon
August 20, 1980

Mr. John Pruitt
Assistant Director, Engineering Division
U. S. Forest Service
P. O. Box 3623
Portland, Oregon 97208

Dear Mr. Pruitt:

This letter is in reply to questions that Mr. Steward of your staff asked during a recent conversation regarding the Swift Project storage and the value of an acre-foot of water annually.

Q-1. Swift Project Storage

Swift Reservoir at elevation 1,000 MSL has a gross storage content of 756,000 acre-feet. At minimum pool elev. 878 (below this level is inactive storage), the storage content is 309,000 acre-feet. Active storage before Mt. St. Helens' eruption on May 18 was 447,000 acre-feet. Today it is less and we expect to have some good data within a few days on how much the active storage has been reduced.

Q-2. Value of an Acre-Foot Annually

This is a more complex matter since the impact is dependent on many factors, such as the type of water year and the market for the energy. However, as I understand your needs, I would suggest you use 700 kilowatt-hours as the amount of power that an acre-foot of water will generate at the Lewis River plants annually. If you would evaluate this energy during the next few years, somewhere between 1 1/2 cents to 3 cents per kilowatt-hour, I would think you should obtain a reasonable annual value of an acre-foot of active storage foregone. This is equivalent to around $10 to $20 per acre-foot annually.

If you have any further questions, please let me know.

Very truly yours,

A. E. Alspaugh

A. E. Alspaugh
Mgr. Civil Engineering

AEA/ka

MOUNT ST. HELENS WATERSHED REHABILITATION

Assessment Of Seeding The Area

To Reduce Sedimentation

Prepared By:

Emergency Watershed Rehabilitation Team
USDA, Forest Service, R-6
Portland, Oregon

For: Arvid Ellson, Director
Mount St. Helens Recovery Planning Unit

and

Bob Tokarczyk
Forest Superivsor, Gifford Pinchot NF

July 23, 1980

Assessment of Seeding to Reduce Sedimmentation
Mount St.Helens Area

INTRODUCTION

The eruption of Mount St. Helens on May 18, 1980, devastated a large area on the Gifford Pinchot NF. Since May 18, this area has already been impacted by severe rill, gully and channel erosion and sedimentation of the Toutle, Green and Muddy River systems. Rainfall amounts since May 18 have been 3 to 5 inches which is 3 percent of the annual precipitation. The Watershed Rehabilitation Team is considering many remedial actions. The Team's objective is to make recommendations for immediate short range rehabilitation measures needed within the Forest boundary to protect life, health and property both on and off the National Forest. This interim report documents the Team's decision process to evaluate and develop a program of grass seeding to reduce erosion and subsequent sedimentation into the main channels this Fall and next Spring.

Any revegetation measures that would be effective in the Fall of 1980 must be taken immediately. Therefore, this report deals only with an assessment of seeding grass and forb mixtures for erosion reduction. Other sedimentation reduction measures will be evaluated in the Emergency Watershed Rehabilitation Team report due August 15, 1980.

II. PROCEDURE

The Team spot-sampled selected locations after a thorough analysis of post-eruption color and color infrared photography. Team members observed and recorded existing conditions, conducted scientific tests, collected samples, and photographed typical conditions on the ground. The ground area was also observed from low level helicopter flights.

Samples collected were subjected to various soils, watershed, and physical properties tests at Regional Office and Oregon State University laboratories. Data was developed for use in standard watershed stability, erosion and sediment yield equations based on physical properties of the surface materials, infiltration rates, and cover information. These tests and calculations are the basis of the following analysis.

III. SITUATION

A Site Conditions

An area within the proclaimed boundary of the Gifford Pinchot National Forest was heavily impacted by the eruption and blast as was adjacent private and State of Washington lands. It is estimated that 110,000 acres were damaged by the blast with about 83,436 acres within the Forest boundary. Those conditions which effect plant growth are summarized below:

1. Elevation - The entire National Forest portion of this area lies above 1900 feet elevation. The average between highest and lowest elevations for the area is 5150 feet. Prior to the eruption timberline on the mountain was approximately 4400 feet. However, above this elevation trees were reduced in stature and resembled

those growing in subalpine to alpine conditions. There are 21,676 acres above the 4400 foot elevation.

2. Slope - the National Forest portion of the area is generally steeper, rougher, and more broken than terrain of the adjacent state and private lands. The area below 4400 feet with 30 percent or less slopes is 19,955 acres. The remainder of the area, has slopes greater than 30 percent. Many slopes exceed 65 percent.

3. Ash and Soil Conditions - Investigations by the Team have revealed several ash and soil conditions which will affect the success of erosion control measures by vegetative means.

   Ash depths vary from 1 to 15 inches within the affected area with the deepest accumulations being found in the Clearwater, upper Bean, and Smith Creek Drainages. Depending on location, ash deposits have 2 to 4 layers with finer materials at the surface. The test on the surface material shows 75% passing the 200 sieve. Initial infiltration measurements taken in the field show 2 to 5 inches per hour on a flat surface, starting with a 4 inch head.

   More testing is being conducted. Permability rate range from 1.6 x 10 -2 to 8.0 x 10 -5 cm per sec. It is anticipated that high intensity rain on the ash surfaces on steep slopes will result in high surface runoff. Rills develop immediately on the slopes above 30 percent.

   Chemical analysis of the ash shows available plant nutrients to be low (Total N, .0.1%, P 3 PPM, K 150 PPM). Past experience has shown that projects conducted in areas where nutrient levels are equal to or better than ash materials in the Mount St. Helens area require initial and maintenance fertilizer application to achieve even low percentages of plant establishment. Organic matter content is also very low to nonexistent in the upper layers.

4. Moisture Conditions - Moisture conditions of the affected area are good for plant growth and for seedling establishment once the root radical penetrates the upper one and one half inch of dry crust.

   The ash has formed a barrier to evaporation that has held last winter's moisture within the soil mantle.

   Profile pits dug to determine depth of ash and areas of plant rooting have indicated in most cases that the buried soil contains large amounts of water. It is questionable that any additional moisture has entered the soil profile except in localized cases since May 18.

   Riparian zones have more moisture as would be expected. The buried soil on steeper slopes and ridges was dryer.

B. <u>Erosion Mechanics</u>

Sheet, rill, and gully erosion of both the ash and the native soil is developing at a rapid rate and will be difficult to stop. Once water is channeled in a rill or gully system, the force of moving water is great enough to keep rills growing both longitudinally and laterally. This is especially true on slopes in excess of 30 percent where vegetation was previously removed, such as clearcuts where less woody debris remains. Due to the density and channelization properities of the ash, rill and gully

systems quickly reach the original soil layer. This intensifies the erosion potential and may contribute to sediment loads many years into the future. The possibility also exists that the ash will liquify on steep slope and move as a mass. This phenomenon was observed in the field on a small scale.

The most severe gully and channel bank erosion was observed on the North Toutle, where pyroclastic deposits have been deeply incised. South Toutle and Muddy drainages show similar effects but to a lesser degree.

Measured rill and gully erosion on slopes, varied from 5 to 540 tons per acre for a six-week period. Measured transects of channel erosion had values of 3 to 1400 acre feet per mile over the same interval. Precipitation during this period was 3 to 5 inches. However, this is a relatively moderate amount when the annual precipitation, which varies from 70 to 140 inches, is considered.

Most of the deposited material in the stream channels appears easily erodable and it is expected the stream channels will be quite unstable in the near future and meander laterally over the stream bottoms.

Where ash or mudflows have accumulated in stream bottoms adjacent to steep side slopes, there is considerable side-channel erosion and head-cutting occurring due to concentration of water entering the main stream bottom from steep slopes without a break in gradient.

It is anticipated that peak flood in the area will increase from 2 to 20 times from those observed before the eruptions, depending on the extent of damage. Past measured flows have been from 50-159 c.s.m. Measured streamflows in the area on July 8 and 17 varied from 7 c.f.s. to 60 c.f.s. on the Green River and South Fork Toutle respectively.

The most critical runoff areas will be where the soil water-holding capacity is least, such as the heavy blast area. Areas of heavy ash deposit overlying undisturbed natural soil could have increased water-holding capacity if infiltration rates were not reduced. In several areas water has been observed to run off after superficial wetting of the crusted material. Once the crust is broken however, infiltration rates increase, largely depending on the material under the crust.

Snowmelt will be considerably accelerated over most of the area due to shade removal which will permit solar radiation and wind movement to be more extreme. Normally, the most critical elevations will be between the 2000-3500 feet elevation.

The pyroclastic flow down the North Toutle created impoundments on both Coldwater drainages with the capacity of 200,000 acre feet. The new Spirit Lake Basin has a capacity of 500,000 acre feet. This impoundment will prevent any flow or sediment transport to the Toutle drainage in the Fall of 1980 and the Spring of 1981. Of the total area draining from the National Forest into the upper North Toutle, 65 percent is trapped by these impoundments.

C. Vegetative Conditions

Both annual and perennial native herbaceous vegetation is recovering more rapidly than anticipated on the North and West slopes (those not in the direct blast path) where ash deposits are not more than 4 to 6 inches deep. Areas with deeper deposits are also recovering, but more slowly. Thistle and fireweed are expected to produce seed this Fall.

Unidentified seeds were observed germinating in native soil of Coldwater Canyon where ash had been eroded away.

Very little recovery was noted on the South slopes which received the force of the blast along the North Toutle River and in the Spirit Lake Basin. Much soil on these slopes has been displaced.

Conditions for further recovery of native vegetation appear very good. The dry surface layer of ash has formed a mulch which preserved existing soil moisture available for native herbaceous plants to initiate regrowth. Topkilled shrubs, such as vine maple, and alder on the perimeter of the devastated area are resprouting.

No live tree seedlings were found on the two planted clearcuts.

Down timber covers much of the affected area on National Forest land. The area was covered with old and second growth timber stands that contained volumes of up to 100,000 board feet per acre. The only areas that are completely devoid of down timber are those slopes that directly face the volcano and clearcut blocks.

There is no uniform pattern of distribution of material on the ground. It is found laying in all directions in relation to the slope. Those areas where the majority of timber is lateral to the direction of the slope, have experienced markedly reduced erosion.

The best protecton is afforded when material is uniformly spread over the slope. However, when it is only on portions such as the lower third of the slope, it is still effective in making a reduction in sediment yield compared to adjacent, totally bare areas. This was observed in the Green and Clearwater drainages, where heavy volumes of timber were blown down. The Toutles, Bean and Smith drainages have much less timber on the ground and more severe erosion.

D. Existing Management Prescriptions

The blast area containing significant evidence of the volcanic effects is being studied for special management opportunities. The present management prescription provides for curtailment of any site modifying activities until final prescriptions and boundaries are established. Seeding would not be allowed in this unit unless it would prevent significant damage to downstream watersheds outside the special management area. In addition, most of the same area is in a Further Study Area resulting from RARE II decisions. These overlying management prescriptions will influence any remedial actions.

Numerous research programs are being conducted throughout the area and minimizing conflict with these programs is necessary.

IV. ANALYSIS

A. Revegetation

It has been proven elsewhere that vegetative cover reduces over surface flow, rain drop splash erosion and provides for increased infiltration into the soil mantle. The amount of benefits derived are directly proportinate to the density of the vegetative cover. The steeper the slope the less effective is any given amount of cover. Because of the poor seed bed conditions described, steep slope and dry crust, a low percent of ground cover from establishment is expected on slopes over percent.

Heavy standing crops of grasses and forbs provide an excellent protective layer for the soil surface. Root masses also provide a binding medium that will many times reach six feet or more in depth. These benefits take more than several years to accrue. Initial plantings of grasses on excellent agricultural sites followed by irrigation seldom reach more than a 70 percent density in the first year and do not obtain their maximum density until the third or fourth year. Within those time frames the Mount St. Helens area will be disturbed by timber salvage operations and by other erosion control measures taken.

Other types of vegetation or organic material can provide erosion protection. Excellent sources of erosion protection in the Pacific Northwest include down trees, standing dead trees, or thick layers of organic debris. In many areas standing dead timber with its accompanying residue layer on the soil provides a very stablizing effect on soils and controls erosion to almost the same extent as grasslands in excellent condition. In the areas of standing damaged timber return of the understory will soon re-establish these erosion control conditions without seeding.

The situation presented within blast area of the eruption is quite different in several respects from that encountered in past experience with wildfire erosion control seeding. These differences include:

1. Ash depth and texture - In average fire rehabilitation situations wood ash depths of two to three inches are encountered and is usually fluffy, allowing penetration of seeding materials and water. The eruption area presents ash depths ranging from 1 to 15 inches with a hard crusted surface that does not allow penetration of seeding materials and creates a low rate of infiltration of precipitation. This is intensified by steep slopes.

2. Soil nutrient levels - Generally fire ash is high in the principal growth nutrients necessary for establishment of plant materials. If fertilization is necessary it is only to get rapid early grow. Following this the planted materials are able to derive their own nutrients. The volcanic ash, however, is almost devoid of the principal plant growth nutrients. To obtain and maintain herbaceous plant growth, will take continuous fertilization.

B Erosion Mechanics

In the blast area high volumes of timber have been left laying on the slopes. Material in place this Fall and next Spring will provide a very effective barrier to sediment transport and rill formation A high precentage of the Toutle and Green River drainages on National Forest land was not previously logged and the down timber is in place. The areas of severe blast effects are within the closed Coldwater and Spirit Lake Basins.

Most of the sediment transported out of the area will come from gully and channel erosion carried by high volumes of flow due to accelerated snowmelt and lack of water-holding capacity. Grass seeding can be effective in reducing surface erosion, however surface erosion is a minor contributor to the overall sediment problem.

C Additional Benefits

It is recognized that there are benefits from seeding other than erosion reduction. Seeding may establish a nursery crop to help stimulate future growth especially in riparian zones. Decaying organic material from vegetation helps retain water and make nutrients more available to new plant life. Seeding may provide forage adjacent to standing timber. These benefits would be maximized if complete drainages were seeded.

D Criteria

The following criteria is establish for the areas which would be recommended for seeding. They are:

1. Only areas below 4400 feet in elevation would be seeded.

   Historical information and field observation of surrounding areas indicated that the upper levels of commercial timber and significant herbaceous plant grow in the area prior to the eruption was below this elevation.

2. Only areas on slopes of less than 30 percent will be seeded.

   Establishing plant growth requires that a stable seedbed be present. Field observations indicated that on slopes of greater than 30 percent this stability was not present. Additionally, the present crusted surface does not present an acceptable seed bed. On slopes of greater than 30 percent seed and ferilizer would not be retained, but would be washed or blown to slopes with lesser gradients.

3. Areas of standing timber, either dead or dying, will be excluded.

   Field observations indicated that the understory of these types of areas had not been greatly effected. Both shrubs and herbaceous species are making significant regrowth.

4. Areas with ash depths in excess of six inches would not be seeded. Ash depths in excess of six inches provide basically a biological desert for establishment. The hard surface layer of the ash make germination and root penetration extremely difficult, and this absence of moisture in the upper several inches of the material would deter root radical penetration.

5. Areas to be seeded must be greater than 100 acres. The economics and logistics of aerial application of seed and fertilizer require that treatment areas must be at least one hundred acres in size.

6. Areas within Management Unit One will not be seeded. Substantial protection of downstream channels is already provided by downed timber. In addition, 65 percent of the National Forest drainage area into the North Toutle is behind the entrapments provided by Spirit Lake and the impoundments on Coldwater Creek. A high percentage of the slopes are over 30 percent or 4400 feet.

7. Seeding and especially fertilizer will interfere with scientific research on the high lakes and upper Clearwater. These immediate areas will be avoided.

V SEED MIXTURE

The primary reason for seeding in the impact area is to establish herbaceous ground cover which will reduce erosion and sedimentation into the major river systems of this area. To accomplish this will require that this vegetation be established during the Fall of 1980. Plant establishment should provide limited surface protection during fall and early winter rains.

The seeding mixture developed to meet this need is composed primarily of winter annual plant materials. These species grow well in the cool, wet conditions that typify the Fall and early Winter in the Mount St. Helens area. Additionally to insure that protection, once established will be continued over a period of years, a perennial component is necessary. This component will establish more slowly than the winter annuals, but should provide cover for a number of years. This perennial should also be one that will develop rapidly and is vigorious, but which at the same time is relatively short lived. This will be be important factor on the areas which will be reforested in the next two to four years. Minimal competition between herbaceous material established and trees planted is the primary consideration on most of the areas proposed for seeding.

The proposed seed mixtures listed below were developed to accomplish rapid revegetation. The intent is to utilize the Priority #1 seed mixture on the entire project. However, the quantities of seed necessary to accomplish a project of this magnitude may not be available. If enough seed is not available to use the Priority #1 mixture for the entire area seeded, then Priority #2 or #3 mixtures can be substituted with no loss of effectiveness. The key is to meet the prescribed pounds of pure live seed per acre.

	species	Pure live seed/sq. ft. for 1 lb. of seed	recommended pounds/ac.
PRIORITY 1	Annual Ryegrass 1/	4.5	15
MIXTURE	Perennial Rye-grass 1/ or	5.0	10
	Hybrid Ryegrass		
	Subterranean clover 1/	1.5	4
	Hairy vetch 1/	0.5	4
	Total	11.5	33
PRIORITY 2	Annual Ryegrass 1/	4.5	25
MIXTURE	Subterranean clover 1/	1.5	7
	Total	6.0	32
PRIORITY 3	Ryegrass (any) 1/	4.5	20
MIXTURE	Field Brome-grass 1/	1.0	10
	Subterranean Clover 1/	1.5	4
	Crimson Clover 1/	3.0	4
	Yellow Sweet-clover 1/	6.0	2
	Total	16.5	40

1/ Grass or Forb Species.

GRASS

1. Field Bromegrass - Bromus arvensis
2. Perennial Ryegrass - Lolium perenne
3. Annual Ryegrass - Lolium multiflorium
4. Hybrid Ryegrass - Lolium hybridum (var astor)

FORBS

Subterranean Clover - Trifolium subterranean
Hairy Vetch - Vicia villosa
Hungarian Vetch - Vicia pannonica
Winter Vetch - Vicia villosa var varia
Crimson Clover - Trifolium incarnatum
Yellow Sweetclover - Melilotus officinalis

Pure live seed per square foot should range between 50 and 150 seeds per square foot. This range will guarantee establishment of a satisfactory stand.

Analysis of the ash material has indicated that it is almost devoid of the essential growth nutrients. Establishment and maintenance of any grass/forb seedings will require considerable fertilization. An initial application, at the time of seeding of 200 pounds of 27-12-0, followed by a Spring 1981 application of at least the same amount is recommended. The latter application should be made prior to May 31, 1981, if it is possible.

The application of seed and fertilizer should be completed by no later than September 15, 1980. Prior to application of legume seed, inoculation with the proper nitrogen fixing bacteria should be accomplished. This should be no sooner than 24 hours before field application of the seed.

VI RECOMMENDATIONS

The following areas are recommended for seeding in the order of highest expection of attempting to meet a sediment reduction objectives.

1. No seeding will be proposed in Management Unit #1.

   Establishment of cover in most of this area would be minimal. Less than ten percent ground cover would be anticipated. This amount of cover would not be sufficent to prevent accelerated rill and gully erosion and head cutting.

2. No seeding in standing timber.

3. Seed areas of less than 30 percent slopes, predominantly without down timber, in blocks larger than 100 acreas below 4400 feet elevation with less than six inches of ash: Refer to Map for block numbers).

   a. Upper Green River - Blocks 4 and portions of Block 3 - 1444 acres.

   b. Clearwater drainage - Block 5 Acres 1837 acres.

   SUBTOTAL 3281 acres.

4. Riparian zones with slopes less than 30 percent, less than 4400 feet in elevation, with down timber and with less than six inches of ash:

   a. Upper Green River - Portion of Block 3 Acres 125 acres.

   b. Clearwater Drainage - Portion of Block 5 Acres (included in 3b).

   SUBTOTAL 3406 acres.

5. Riparian zones with slopes less than 30 percent, less than 4400 feet in elevation without down timber, and with more than six inches of ash.

   a Smith Creek - Block 8 - 704 acres.

   SUBTOTAL 4110 acres.

6. Criteria Evaluation Area - All conditions represented.

   a. Clearwater west slope - Block 6 - 794 acres.

7. Some benefits along with possible sediment reduction are possible from treating an entire drainage.

   b. Bean Drainage - Block 7 - 4890 acres.

TOTAL 9794 acres

APPENDIX

Additional Documentation
USDA, Forest Service, Region 6

1. Aerial Photographic Coverage

    a. Pre eruption

(1)	1:12,000	True Color	(1979)
(2)	1:80,000	B&W	(mid 1979)
(3)	1:120,000	CIR	(May 1, 1980)

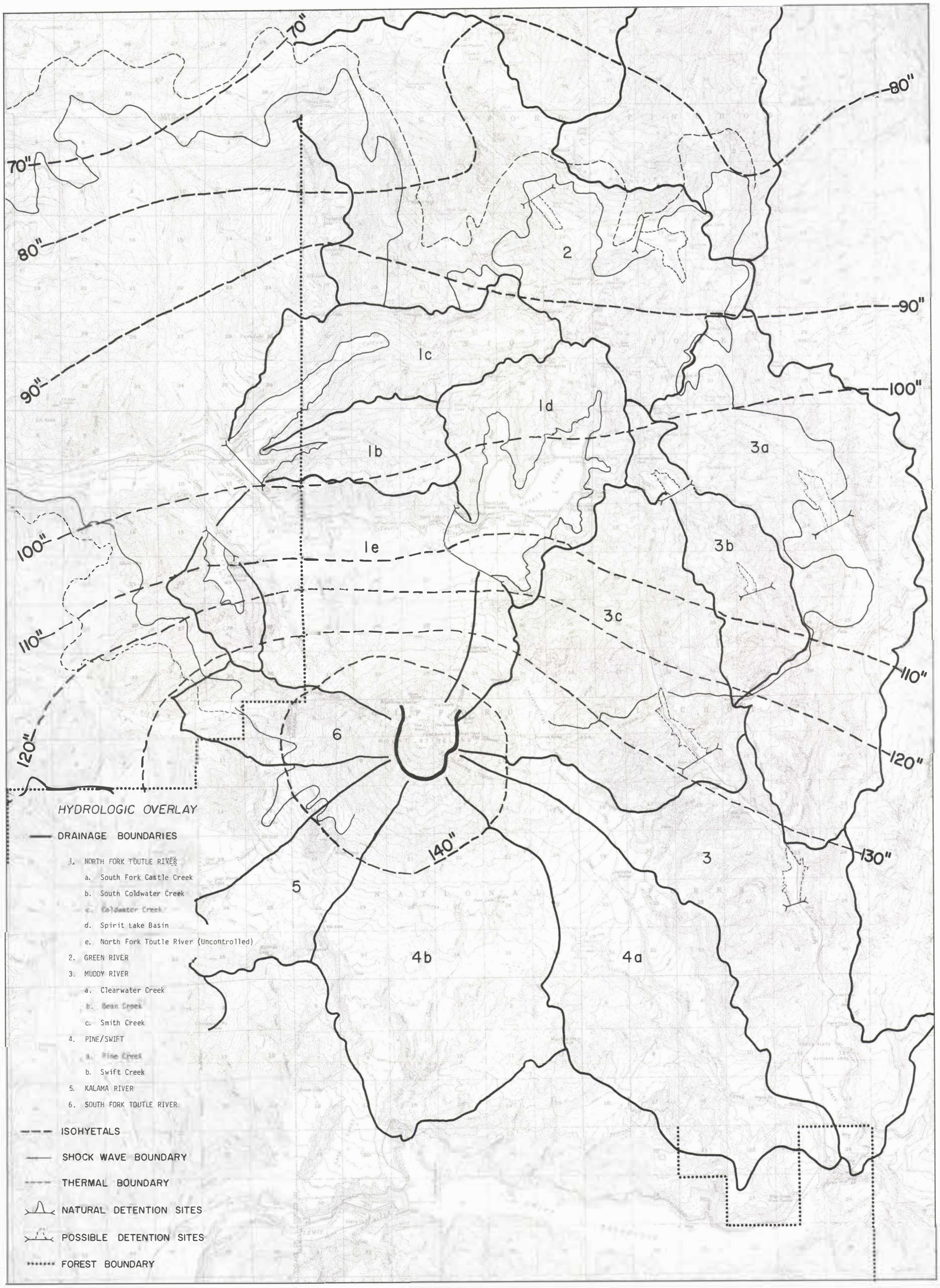
    b. Post eruption

(1)	1:24,000	True Color	(June 19, 1980)
(2)	1:30,000	CIR	(June 19, 1980)
(3)	1:120,000	CIR	(June 19, 1980)

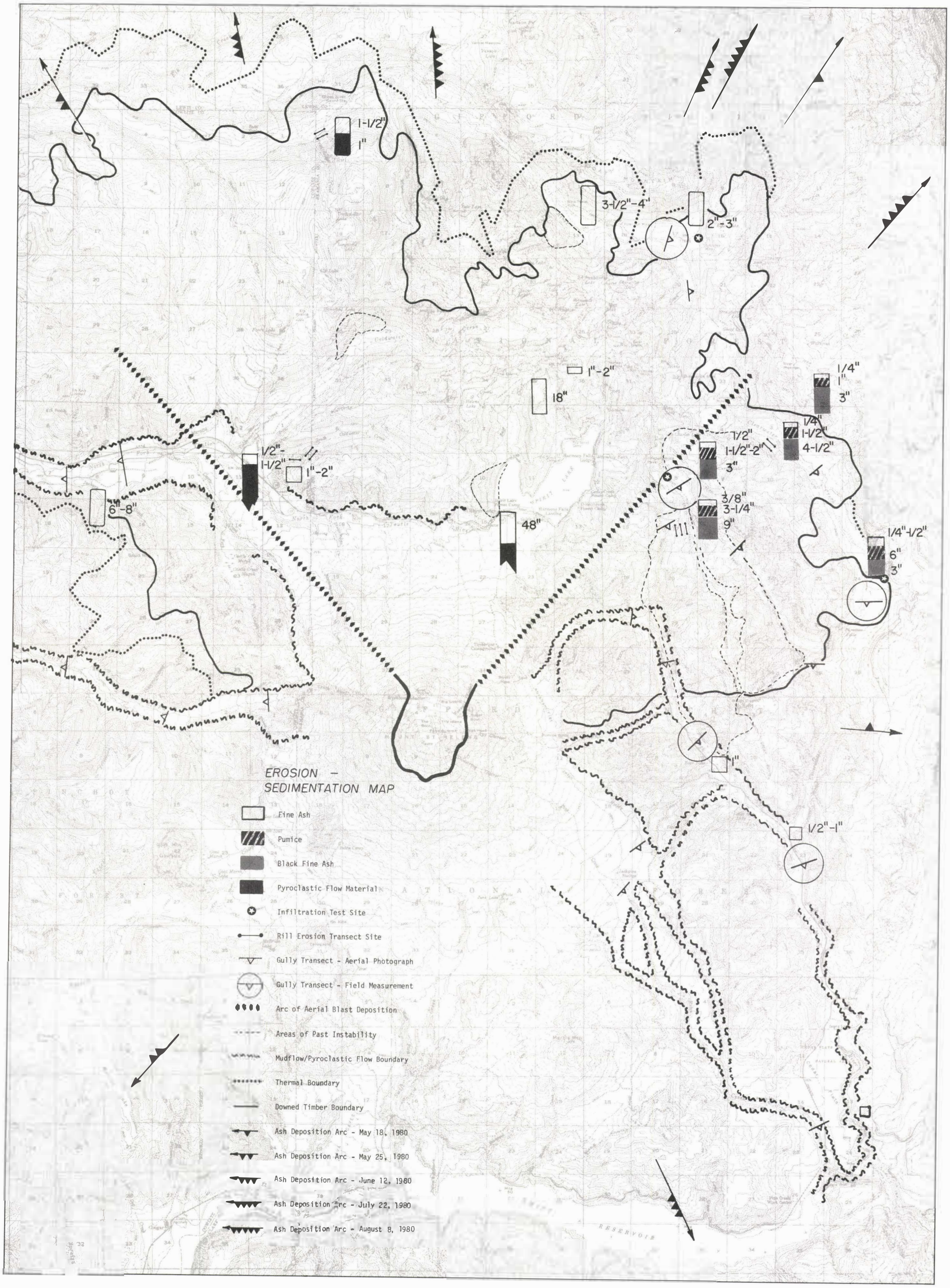
2. Photographic Interpretation Overlays

a.	Volcanic effects	1:100,000
b.	Hydrology	1:24,000
c.	Vegetation	1:24,000
d.	Transportation	1:24,000

3. 35 mm slide coverage of ground and aerial observations

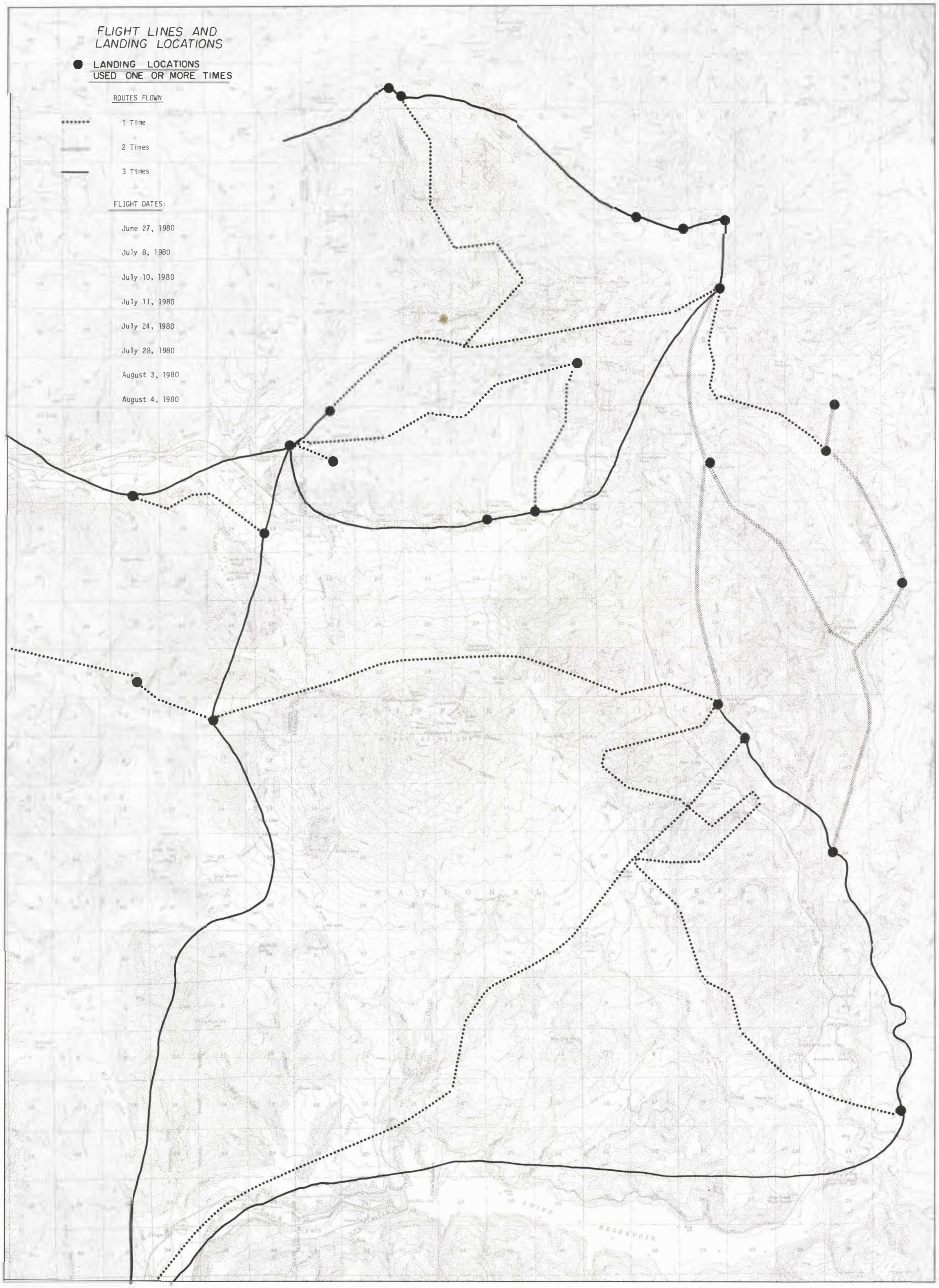


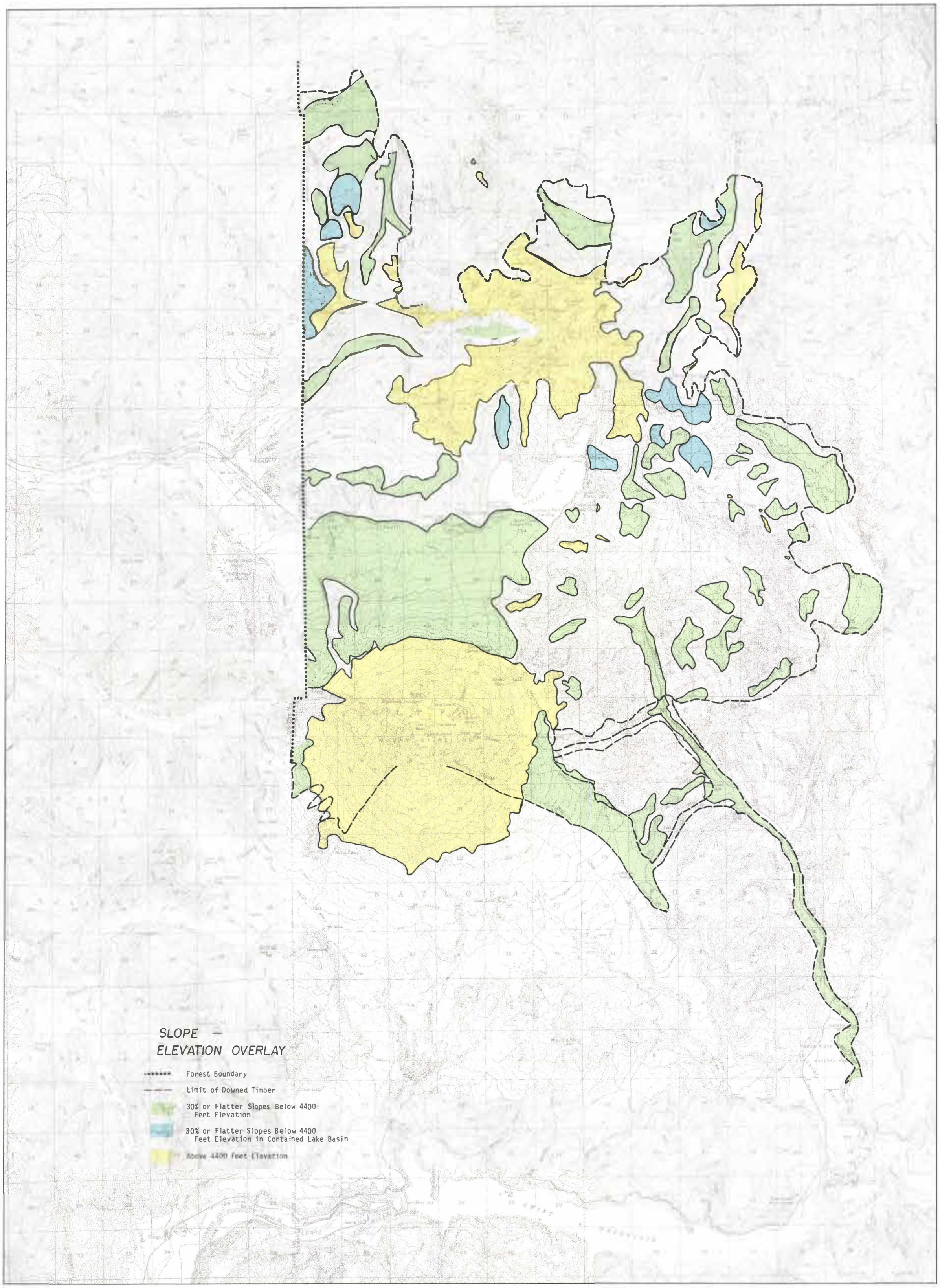
HYDROLOGIC OVERLAY
DRAINAGE BOUNDARIES
1. NORTH FORK TOUTLE RIVER
a. South Fork Castle Creek
b. South Coldwater Creek
c. Coldwater Creek
d. Spirit Lake Basin
e. North Fork Toutle River (Uncontrolled)
2. GREEN RIVER
3. MUDDY RIVER
a. Clearwater Creek
b. Bean Creek
c. Smith Creek
4. PINE/SWIFT
a. Pine Creek
b. Swift Creek
5. KALAMA RIVER
6. SOUTH FORK TOUTLE RIVER
ISOHYETALS
SHOCK WAVE BOUNDARY
THERMAL BOUNDARY
NATURAL DETENTION SITES
POSSIBLE DETENTION SITES
FOREST BOUNDARY
70"
80"
90"
100"
110"
120"
130"
140"
1b
1c
1d
1e
2
3
3a
3b
3c
4a
4b
5
6



EROSION - SEDIMENTATION MAP
Fine Ash
Pumice
Black Fine Ash
Pyroclastic Flow Material
Infiltration Test Site
Rill Erosion Transect Site
Gully Transect - Aerial Photograph
Gully Transect - Field Measurement
Arc of Aerial Blast Deposition
Areas of Past Instability
Mudflow/Pyroclastic Flow Boundary
Thermal Boundary
Downed Timber Boundary
Ash Deposition Arc - May 18, 1980
Ash Deposition Arc - May 25, 1980
Ash Deposition Arc - June 12, 1980
Ash Deposition Arc - July 22, 1980
Ash Deposition Arc - August 8, 1980
1-1/2"
1"
3-1/2"-4"
2"-3"
1"-2"
18"
1/4"
1"
3"
1/2"-
1-1/2"
1"-2"
1/2"
1-1/2"-2"
3"
1/4"
1-1/2"
4-1/2"
6"-8"
48"
3/8"
3-1/4"
9"
1/4"-1/2"
6"
3"
1"
1/2"-1"

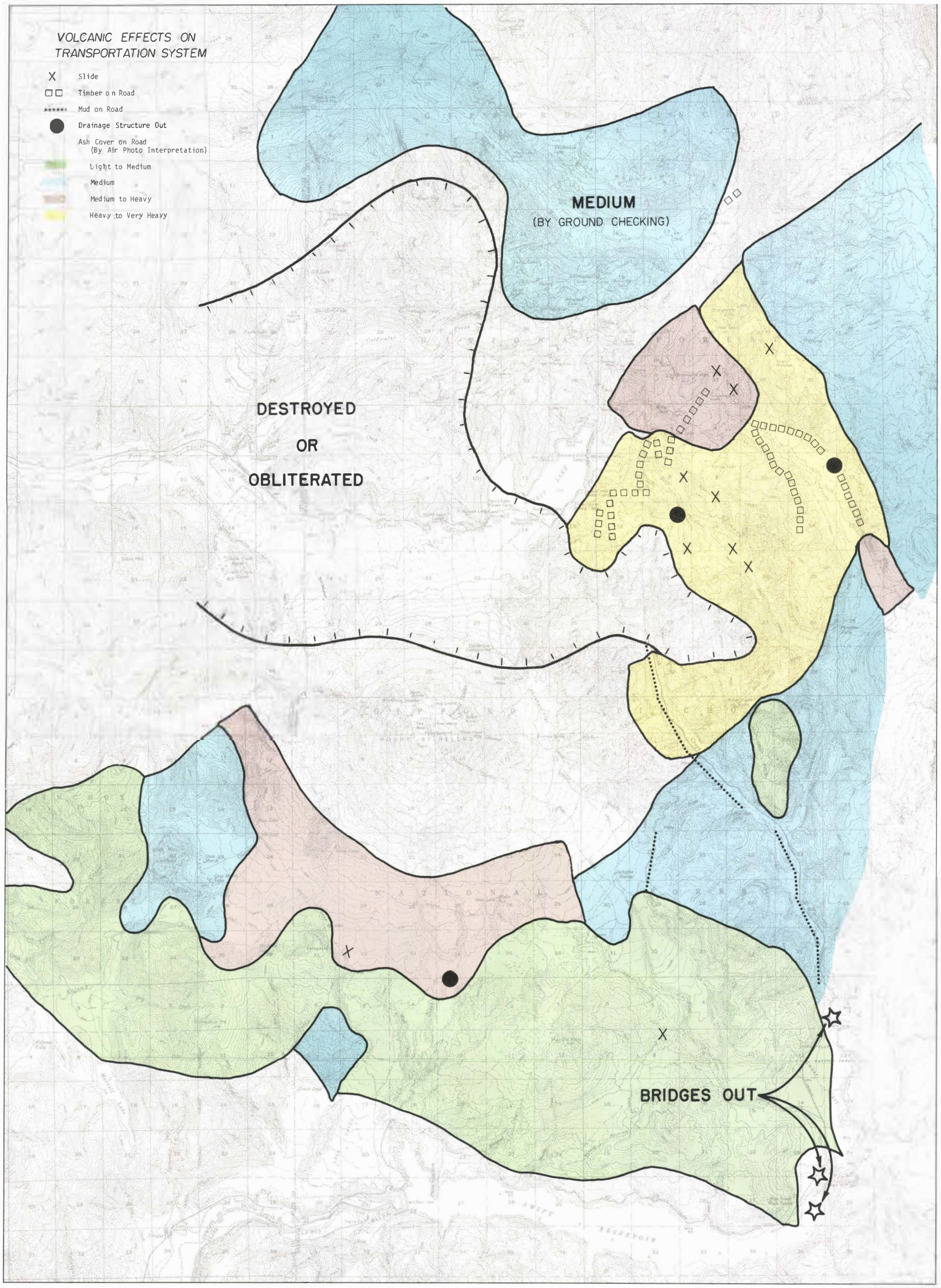
2


FLIGHT LINES AND
LANDING LOCATIONS
LANDING LOCATIONS
USED ONE OR MORE TIMES
ROUTES FLOWN
1 Time
2 Times
3 Times
FLIGHT DATES:
June 27, 1980
July 8, 1980
July 10, 1980
July 11, 1980
July 24, 1980
July 28, 1980
August 3, 1980
August 4, 1980



SLOPE —
ELEVATION OVERLAY
Forest Boundary
Limit of Downed Timber
30% or Flatter Slopes Below 4400 Feet Elevation
30% or Flatter Slopes Below 4400 Feet Elevation in Contained Lake Basin
Above 4400 Feet Elevation

4


VOLCANIC EFFECTS ON
TRANSPORTATION SYSTEM
X Slide
Timber on Road
Mud on Road
Drainage Structure Out
Ash Cover on Road
(By Air Photo Interpretation)
Light to Medium
Medium
Medium to Heavy
Heavy to Very Heavy
MEDIUM
(BY GROUND CHECKING)
DESTROYED
OR
OBLITERATED
BRIDGES OUT